U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-257 709

Destructing Chemical Wastes in Commercial Scale Incenerators Technical Summary. Volume I

Environmental Protection Agency, Washington, D C

Jul 75

271072

PB 257 709

DESTRUCTING CHEMICAL WASTES IN COMMERCIAL SCALE INCINERATORS

Technical Summary

VOLUME I

JULY 1975

FINAL REPORT - Phase 1

Prepared for
U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No. PB-257 709

4. Title and Subtitle
Destructing Chemical Wastes in Commercial Scale Incenerators. Technical Summary. Volume I.

5. Report Date Jul 75

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Environmental Protection Agency, Washington, D. C.
Office of Solid Waste Management Programs

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

The basic output of the Phase I work, described in detail in this report, is an operational plan for determining whether industrial wastes containing hazardous components can be thermally destroyed in an environmentally acceptable manner using commercial scale facilities. This plan is based on: (1) Classification, identification, priritization and selection of wastes such that they provide a reasonable cross section of currently generated industrial wastes, with particular attention to hazardous materials; (2) A careful selection of facilities, chosen to be representative of all feasible engineering approaches based on thermal degradation; (3) Assignment of top priority wastes to specific facilities on the basis that the waste can be expected to be destroyed, transportation and handling of the waste is manageable, and all facilities will be tested using at least one priority waste. A summary presentation for each of the Phase I program activities is provided.

17. Key Words and Document Analysis. 17a. Descriptors

*Solid waste disposal,
*Hazardous materials,
*Industrial wastes,
*Incinerators,
Pyrolysis,
Chemical industry,
Organic compounds,
Classification,
Environmental impacts,
Air pollution,
Sampling,
Chemical analysis,
Performance tests,
Site surveys,
Particles,
Tables(Data).

17b. Identifiers/Open-Ended Terms
Particulates.

17c. COSATI Field/Group 13B, 7A

18. Availability Statement
National Technical Information Service
Springfield, Virginia 22161

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 208p

22. Price 7.75/2.25

THIS FORM MAY BE REPRODUCED

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PREFACE

This report summarizes results of a Phase I study concerned with thermal destruction of suitable industrial wastes in various types of commercial scale facilities. The purpose of this effort was to develop a set of demonstration test plans for each of the selected facilities and wastes. The objective of this planned Phase II demonstration is to verify the technical and economic feasibility of thermal destruction as a viable means of disposing of various organic chemical wastes.

The report consists of two volumes. In the first, a summary of all activities leading to the preparation of the test plans is presented. In addition, planning and preparatory considerations common to all facility test plans are documented. Volume II consists of 14 individual test plans centered on the thermal destruction facilities.

Work reported in both volumes was sponsored by the Environmental Protection Agency, Office of Solid Waste Management Programs under Contract No. 68-01-2966. The EPA Project Officer was Mr. Alfred Lindsey, assisted by Mr. John Schaum. The technical work reported here was accomplished by personnel of TRW Systems and Arthur D. Little, Inc. TRW was the prime contractor for this work and was supported by ADL in the role of a major subcontractor. The Project Manager for TRW was Dr. Robert Ottinger. The ADL subcontract was managed by Dr. John Funkhouser.

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1. INTRODUCTION

During the last four years a number of studies designed to determine the types, quantities, and forms of hazardous wastes, the classes and adequacy of hazardous waste treatment processes, and the changes to be expected over the next 10 years in the generation and treatment of wastes have been sponsored by the Office of Solid Waste Management Programs and the Solid and Hazardous Waste Research Laboratory of EPA. In these studies a large number of wastes generated by various industries have been identified as probably incinerable. Furthermore, in many cases incineration was determined to be the most environmentally acceptable method of disposal and in some cases was the only adequate method of disposal. These determinations were usually based on an approximate description of the waste and its properties and a comparison of its expected behavior with the known behavior of a similar material undergoing thermal destruction. Since both the quantity and quality of information available on the thermal destruction of materials is limited, the comparison of expected with known behavior often involved considerable extrapolation.

In order to improve the data base on the effectiveness of thermal destruction, a number of experimental programs were performed at the bench and pilot scale. The information resulting from these programs included theoretical considerations of the molecular scale decomposition mechanisms, experimental attempts to confirm the decomposition mechanisms and definition of the various degradation products at different operating conditions. These data, determined under reasonably well controlled conditions, have elucidated the behavior of a small number of selected wastes undergoing thermal destruction and have generally been useful in confirming or modifying decisions involving the application of thermal destruction to specific wastes. The final step in assessing the thermal destructibility of actual wastes is to determine the conditions for acceptable destruction in commercial scale facilities and compare these conditions with the results of small scale tests. This final step is also necessary to provide assurance to industry and the public that incineration has actually been demonstrated on a commercial scale using industrial wastes. The information will then provide the EPA a firm basis for establishing guidelines and regulations which are technically, economically, and environmentally realistic. Furthermore, the information will benefit both industry and the EPA by describing specific thermal destruction technologies which appear acceptable in meeting guidelines or regulations while identifying potential problem areas associated with those technologies.

Although many industrial wastes are currently being incinerated in commercial incinerators by waste generators and contract waste disposers, the combustion conditions and the effluents often are not well controlled or monitored, and any information gathered is not available to the public. In order to provide the desired information base and make it available to the government and the public, a demonstration program was proposed by the Hazardous Waste Management Division of the Environmental Protection Agency. A competitive contract was awarded to the team of TRW Systems and Energy and Arthur D. Little, Inc., to design such a program and ultimately to perform it. This present report describes the demonstration program plan and is the result of the Phase I program design effort. Following the review of this report and incorporation of comments, it is intended that the program will be initiated.

This first volume of the report is divided into three major sections. This introduction comprises Section 1. Section 2 provides the summary and conclusions of this Phase I effort. Section 3 describes the Phase I activities including the selection of wastes and thermal destruction facilities, the matching of wastes and facilities, the preparation of the Phase II plan, and the Phase II implementation. The second volume contains the detailed Facility Test Plans.

2. SUMMARY AND CONCLUSIONS

2.1 OVERVIEW

The basic output of the Phase I work, described in detail in this report, is an operational plan for determining whether industrial wastes containing hazardous components can be thermally destroyed in an environmentally acceptable manner using commercial scale facilities. This plan is based on:

- Classification, identification, prioritization and selection of wastes such that they provide a reasonable cross section of currently generated industrial wastes, with particular attention to hazardous materials.
- A careful selection of facilities, chosen to be representative of all feasible engineering approaches based on thermal degradation.
- Assignment of top priority wastes to specific facilities on the basis that: the waste can be expected to be destroyed, transportation and handling of the waste is manageable, and all facilities will be tested using at least one priority waste.

As a result of this work, 50 candidate wastes have been assigned to 14 facilities, ranging in number of wastes per facility from 1 to 7. The total elapsed time associated with each facility test operation varies from 19 to 74 days. The average total cost for each waste test evaluation is approximately $71,400. If all candidate wastes were tested, the total projected cost of Phase II would be about $3.6 million.

A summary presentation for each of the Phase I program activities is provided in the following discussion.

2.2 PRIORITIZATION OF WASTES AND SELECTION OF WASTE SOURCES

With a possibility for thousands of industrial wastes that might qualify for use in this program because of potential hazardous properties, it was necessary to develop a system which effectively and logically permitted a selection of the most feasible candidates. The waste grouping criteria chosen for use in Phase I were elemental chemical composition, physical form, and wase of handling. The first grouping based on elemental composition initially led to 16 classes. Because most of the wastes fell in only three of these 16 classes, they were redivided into four major waste classes. A tabulation of these four waste classes is given in Table 2-1 with the first grouping being only for wastes containing carbon, hydrogen and/or oxygen. All wastes with these three elements would belong in waste class 1 regardless of physical form or hazardous property. A prime reason for using this classification system was to provide a method for recognizing when sufficient wastes with similar combustion characteristics had been located. In addition, recognition of this similarity helped match specific wastes to individual facilities based on the need for pollution control equipment. Criteria relating to physical form and ease of handling were developed and applied during the waste-facility matching steps.

Having developed a system for placing all organic chemical wastes into four groups, it was necessary to develop criteria for prioritizing them both within and between categories. One basis adopted as being useful for waste selection for this program was whether a given waste was representative of others having the same characteristics. Obviously selecting wastes for regulatory control demands very different criteria, but such are not needed for this program.

The basic criteria for developing a series of priority levels were:

- Hazard Rating (r_{max}) - A given compound or waste may have a number of ways in which it is considered hazardous (flammability, oral toxicity, inhalation toxicity, carcinogenic, etc.). For each hazard category, four levels of hazard were established with assigned values of 1, 10, 100 or 1000--the higher the value, the more hazardous. In assigning a hazard value to an individual waste with several bases for being considered hazardous, the highest hazard value was used irrespective of which hazard category the value represented.
- Quantity (Volume) Rating (Q) - Because the data on waste volumes are both sparse and, in many cases, of questionable accuracy, a volume ranking system was developed so that

Table 2-1. Incinerable Waste Classes

Waste Class	Chemical Elements	Example
1	Carbon and hydrogen	Tars from production of styrene
	and/or	
	Carbon, hydrogen and oxygen	Off-specification phenol
2	Carbon, hydrogen and nitrogen	Solid residue from manufacture of aromatic amines
	and/or	
	Carbon, hydrogen, nitrogen and oxygen	TDI manufacture reactor tar bottoms
3	Carbon, hydrogen and chlorine	Vinyl chloride monomer manufacturing wastes
	and/or	
	Carbon, hydrogen, chlorine and oxygen	Phenolic tar from 2,4-D manufacture
4	Carbon, hydrogen, chlorine and nitrogen	Nitrochlorobenzene manufacturing wastes
	Carbon, hydrogen and sulfur	Petroleum refining sour waste
	Carbon, hydrogen and fluorine	Fluorinated herbicide wastes
	Carbon, hydrogen and bromine	Ethylene bromide manufacturing waste
	Carbon, hydrogen and phosphorus	Malathion
	Carbon, hydrogen and silicon	Tetraethyl orthosilicate wastes
	Carbon, hydrogen and sodium	Refinery spent caustic

> major differences between wastes could be recognized. For this, four ranges of waste generation volume were chosen. The ranges selected were 100 M lb/yr, 10 to 100 M lb/yr, 1 to 10 M lb/yr and 1 M lb/yr. These volume ranges were assigned ratings of 1000, 100, 10 and 1, respectively. In addition, when no known quantity was found for a waste stream, a waste quantity value of zero was assigned.

After quantity and hazard ratings were assigned to a waste, the priority level was determined by multiplying the two ratings together. Thus, priority level I is the highest and $Q \times r_{max} = 10^6$, while in level VII, $Q \times r_{max} = 1$.

The list of waste streams considered for selection and ranking was first compiled by utilizing existing TRW/ADL hazardous waste data files and information generated by contractors performing EPA Industry Waste Studies. Concurrently with waste prioritization, generation sources of waste streams were identified by the use of two basic references: the Stanford Research Institute Directory of Chemical Products (1974) and Synthetic Organic Chemicals-United States Production and Sales (1973). After identifying 130 potential waste generators, each was contacted to learn whether they would be interested in supplying wastes suitable for Phase II testing. Finally, 50 wastes were individually ranked and selected for Phase II based on: availability of waste, priority level, availability of alternative waste disposal methods, and feasibility of destroying the waste stream by thermal degradation.

The distribution between priority categories for the selected 50 wastes is shown in Table 2-2. In Table 2-3, selected wastes are described in terms of chemical class, priority category and physical form. It will be noted that the number of wastes in each class is reasonably well distributed to the extent possible.

2.3 SELECTION OF THERMAL DESTRUCTION FACILITIES

Considering all of the potentially feasible thermal destruction processes which are likely candidates for this program, a total of eight types were selected for study on the basis of good engineering judgement. Next, based on knowledge existing within EPA, TRW, and ADL, a list of possible

Table 2-2. Distribution of 50 Selected Wastes Between Priority Levels

Priority Category	$Q \times r_{max}$	Number in Category
I	10^6	1
II	10^5	2
III	10^4	3
IV	10^3	18
V	10^2	13
VI	10	8
VII	1	5
		TOTAL 50

candidate test facilities for each of the processes was developed. This list totaled 75, and each was contacted to learn more about their facilities and possible interest in participating in this program. As a result of this preliminary review, 25 test sites appeared potentially valuable. After visiting all but one of these sites, and applying evaluation criteria, 14 facilities were selected for inclusion in Phase II. Table 2-4 provides a list of the selected facilities by process category.

In evaluating each facility the following criteria were applied based upon telephone contacts and site visits:

- Potential for future in hazardous waste management
- Compatibility of waste form and expected incineration characteristics with incinerator capabilities
- Technical advantages and disadvantages of each type of incineration for a specific waste
- Adequacy of air pollution control equipment
- Availability of adequate sampling points
- Adequacy of instrumentation and monitoring of operating conditions.

Table 2-3. Summary of Waste Streams Selected for Testing

Chemical Class	Number of Wastes	Priority	Physical Form
H-C and H-C-O	1	II	1 liquid
	2	III	1 liquid, 1 solid
	5	IV	2 tars, 1 liquid, 2 sludges
	5	V	3 liquids, 1 tar, 1 solid
Total	13		6 liquids, 2 sludges, 3 tars, 2 solids
H-C-N and H-C-N-O			
	5	IV	1 liquid, 2 tars, 2 solid
	6	V	3 tars, 1 sludge, 1 viscous liquid, 1 semi solid
	2	VI	1 tar, 1 liquid
Total	13		3 liquids, 1 sludge, 6 tars, 3 solids
H-C-Cl and H-C-Cl-O	1	I	1 liquid
	1	II	1 solid
	1	III	1 solid
	3	IV	2 liquids, 1 tar
	1	V	1 tar
	2	VI	1 liquid, 1 tar
	1	VII	1 tar
Total	10		4 liquids, 4 tars, 2 solids
Other Wastes			
A. N and Cl containing wastes	2	IV	1 liquid, 1 tar
	1	VI	1 solid
B. Sulfur containing organics	1	VI	1 liquid
	2	VII	1 liquid, 1 tar
C. Fluorine containing organics	1	VII	1 liquid
D. Bromine containing organics	1	V	1 liquid
E. Phosphorus containing organics	1	VI	1 liquid
	1	VII	1 liquid
F. Silicon containing organics	1	VI	1 liquid
G. Mixture of organics and sodium salts or caustic	3	IV	3 liquids
Total	14		11 liquids, 2 tars, 1 solid

Table 2-4. Selected Processes and Facilities

Process Category	Facility	Location
Liquid Injection Incineration	Marquardt Company	Van Nuys, Calif.
	General Electric Co.	Pittsfield, Mass.
	Prenco Manufacturing Company	Madison Heights, Mich.
Multiple Hearth Incineration	Eimco BSP	Belmont, Calif.
Rotary Kiln Incineration	Hyon Waste Management, Inc.	Chicago, Ill.
	Pollution Controls, Inc.	Shakopee, Minn.
	Chem-Trol Pollution Controls, Inc.	Model City, N. Y.
Catalytic Combustion	B.F. Goodrich Chemical Company	Calvert City, Kentucky
Molten Salt Pyrolysis/ Combustion	Atomics International, Division of Rockwell International	Canoga Park, Calif.
Pyrolysis	Surface Combustion Div. Midland-Ross Corp.	Toledo, Ohio
Fluidized Bed Incineration	Hazen Research, Inc.	Golden, Colorado
	Systems Technology Corp.	Dayton, Ohio
Wet Air Oxidation	Resource Recovery Systems, Barber-Colman	Irvine, Calif.
	Zimpro, Inc.	Rothschild, Wisc.

- Safety equipment and procedures
- Willingness of the facility management to be associated with this study.

Although all of these criteria were important in the decision process, other factors were considered such as potential for resource recovery, the ability to conduct a controlled test burn, and the scale (size) of the facility. Emphasis was given to the latter consideration since the objective of Phase II is to evaluate thermal destruction characteristics of actual industrial wastes processed in commercially available facilities. Therefore, it was necessary to find facilities that would be considered commercial scale units. This was successfully accomplished for all categories except the multiple hearth and molten salt processes. Municipal multiple hearths could be made available; however, the ability to run controlled,meaningful test burns would be reduced. A pilot scale unit, used by the manufacturer as the design basis for full scale commercial plants, was chosen in this instance. This unit will permit the acquisition of good quality data representative of larger commercial systems. In the case of molten salt units, no commercial scale plants exist. A large pilot unit was selected as the only alternative.

2.4 FACILITY AND WASTE MATCHING

Once the 14 facilities and 50 wastes were identified for Phase II, each of the wastes was assigned to a specific facility. Matching was accomplished by comparing facility capabilities and limitations with waste characteristics. Indeed, waste-facility matching was primarily dependent upon consideration of the following waste characteristics:

- Physical form: gas, liquid, slurry, sludge or solid
- Temperature range required for destruction: above 2000°F, 1400° to 2000°F, 700° to 1400°F, or below 700°F
- Off gases: primarily oxides of carbon, hydrogen, or nitrogen; but also halogen, sulfur, phosphorus, or volatile metal species
- Ash: nonfusible, fusible, and/or metallic
- Heating value: above 10,000 Btu/lb, 5,000 to 10,000 Btu/lb, or below 5,000 Btu/lb.

A summary of the facility-waste matchings is given in Table 2-5. In addition, Table 2-6 shows the number of wastes within a prioritization category assigned to each facility. It is apparent that the major facility types (liquid injection, rotary kiln and fluidized bed) will test a majority of the wastes.

2.5 PHASE II TEST PLAN AND IMPLEMENTATION

Implementation of Phase II centers on a series of 14 facility test plans. These plans, contained in Volume II of this report, provide: detailed information on each thermal destruction process, wastes to be burned, operational and logistical requirements and limitations, facility instrumentation and pollution control equipment, test burn sequencing, and sampling methods. Effort will also be devoted to the safe physical handling of wastes and residues. At the conclusion of each facility test program (including data evaluation and analysis) a complete report will be issued summarizing the results. An outline of the report format is also provided with each plan. The total cost associated with each facility demonstration program is also provided in the respective plans.

The overall Phase II schedule plan is provided in Figure 2-1. It is constructed in a manner which shows the division of field test work to be accomplished by the TRW and ADL teams. Field test operations are roughly divided along geographical lines to minimize costs.

To insure continuity, the Core Team concept, which was instrumental to the success of Phase I, will be continued in Phase II. The Core Team members will include key personnel of EPA, TRW, and ADL. The objectives of the Core Team is fourfold:

- Review technical progress and related problem areas.
- Provide and ensure a forum for the interchange of data and information
- Coordinate subsequent project activities including any changes in technical direction
- Ensure that all views and inputs have been recognized and utilized.

Approximate dates and the locations of Core Team meetings are shown in Figure 2-1 These meetings are timed to coincide with critical points in the Phase II effort.

Table 2-5. Waste/Facility Matching Summary

Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation
Marquardt Co.	**Eimco BSP**	**Pollution Controls**	**B.F. Goodrich**	**Atomics International**	**Surface Combustion**	**Systems Technology**	**Zimpro, Inc.**
Off-spec isoprene Hexachlorocyclopentadiene still bottoms Organophosphate pesticides (malathion) Waste from polymer polyol production (polymerization of styrene with acrylonitrile) Dodecyl mercaptan wastes Fluorinated herbicide waste	Reactor bottoms from PVC manufacture Aromatic amine residues Isophthalic acid and terephthalic acid still bottoms	Epichlorohydrin manufacturing wastes Steam still bottoms from aniline and alkylated phenol production Acrylonitrile manufacturing wastes Reactor tar bottoms from adiponitrile manufacture Phenolic tar from 2,4-D manufacture Chlorotoluene production wastes Phenylamine tar wastes	Vinyl chloride monomer manufacturing wastes - dichloroethane and heavy chlorinated hydrocarbon wastes that contain vinyl chloride	DNT/MNT mix waste from DNT production Dichloroaniline still bottoms Phenolic tar from MCPA manufacture	API separator bottoms Tars from production of styrene Rubber manufacturing waste sludge Tars from production of phthalic anhydride (xylene process)	Off-spec phenol Amiben manufacture liquid wastes Carbaryl manufacture wastes Ethylene manufacturing wastes Wastes from toluene diamine (TDA) production from dinitrotoluene (DNT)	Coke plant wastes Petroleum refining sour wastes
General Electric Co.		**Hyon Waste Management**				**Hazen Research**	**Resource Recovery**
Ethylene glycol manufacture residue Waste residues from alkyl benzene production Perchloroethylene manufacture still bottoms		PCB (polychlorinated biphenols) wastes in capacitors Evaporate residue from the cumene process for phenol manufacture Nitrochlorobenzene tars Catch basin grease, nitrile pitch from production of surface active agents TDI manufacture reactor tar bottoms Diphenylamine (DPA) manufacture reactor tar bottoms Mercaptobenzothiazole (MBT) tars				Tetraethyl orthosilicate wastes Organic wastes from pharmaceutical manufacture Organic peroxide manufacturing wastes (from dicumyl peroxide manufacture) Ethylene bromide manufacturing wastes Urethane manufacture wastes	Refinery spent caustic Dinitrophenol wastes from dye manufacture
Premco Manufacturing		**Chem-Trol Pollution Services**					
Still bottom from acetaldehyde production and by-product recovery operation Alkyl and aryl sulfonic acid wastes		Chem-Trol proprietary blended waste (high chloride organics)					

Table 2-6. Distribution of Wastes Between Facilities

	Facility	Waste Assignment							
		Number for Each Priority Category Allocated							
Process Type	Name	I	II	III	IV	V	VI	VII	Total
Liquid Injection	Marquardt Co.	-	-	1	1	-	2	2	6
	General Electric Co.	-	1	-	2	-	-	-	3
	Prenco Mfg. Co.	-	-	-	-	1	1	-	2
	Total								11
Rotary Kiln	Pollution Controls, Inc.	-	-	-	2	3	2	-	7
	Hyon Waste Management	-	1	-	3	2	-	1	7
	Chem-Trol Pollution Controls, Inc.	-	1	-	-	-	-	-	1
	Total								15
Multiple Hearth	Eimco BSP	-	-	1	1	1	-	-	3
Molten Salt	Atomics International	-	-	-	-	1	1	1	3
Wet Air Oxidation	Resource Recovery Systems	-	-	-	1	1	-	-	2
	Zimpro, Inc.	-	-	-	2	-	-	-	2
	Total								4
Fluidized Bed	Hazen Research, Inc.	-	-	-	-	2	2	1	5
	Systems Technology Corp.	-	-	1	2	2	-	-	5
	Total								10
Pyrolysis	Surface Combustion Division Midland-Ross Corp.	-	-	-	3	1	-	-	4
Catalytic Combustion	B.F. Goodrich Chemical Co.	1	-	-	-	-	-	-	1

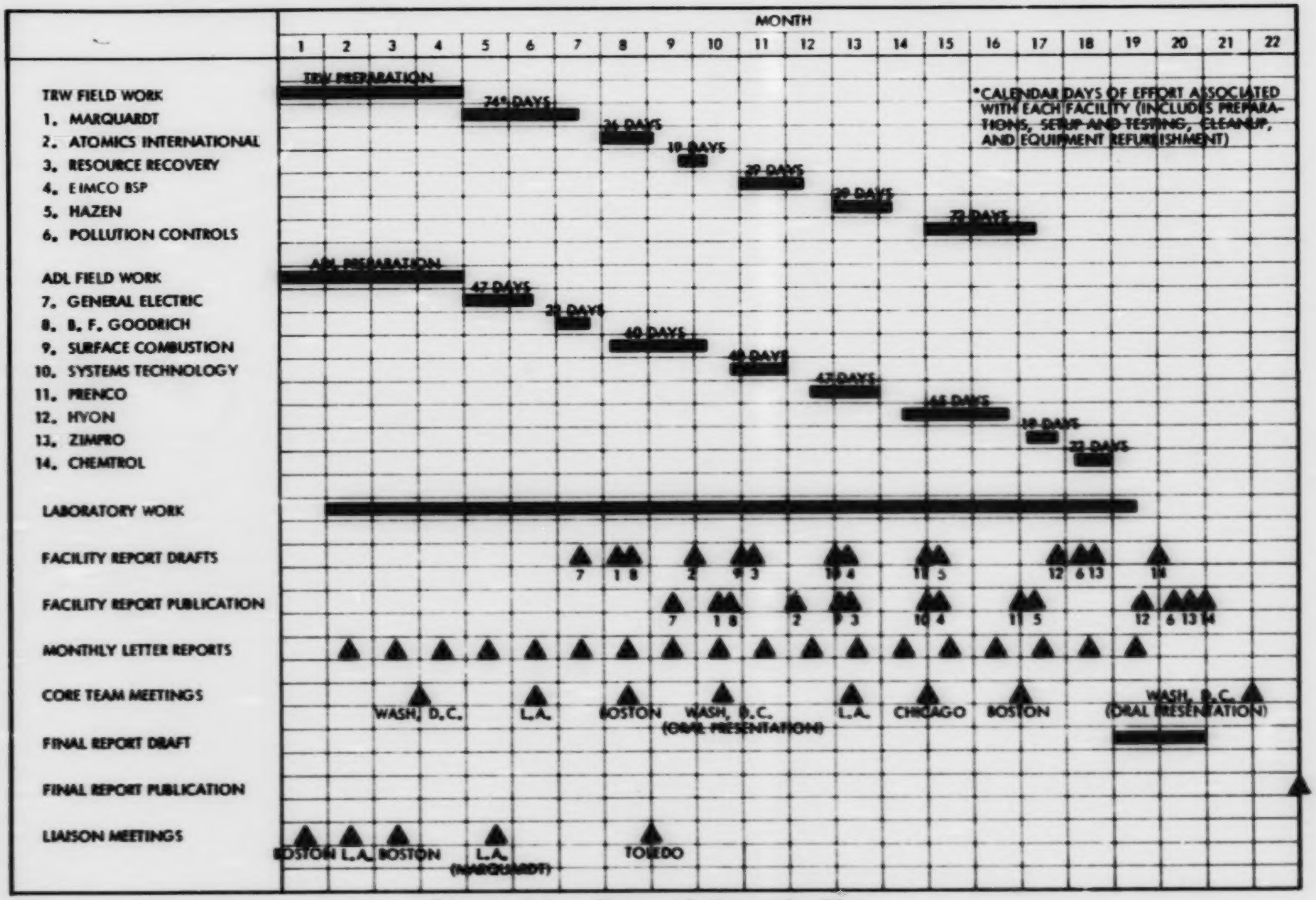

Figure 2-1. Phase II Schedule Plan

3. PHASE I ACTIVITIES

3.1 WASTE SELECTION AND PRIORITIZATION PROCESS

Major objectives of Phase I were to add to, modify, and clarify the component wastes on the preliminary list of hazardous waste streams provided by EPA, characterize the waste streams to the degree necessary, and develop a final prioritized list of 50 waste streams.* Concurrent with the development of the prioritized list of waste streams, potential sources of hazardous wastes for thermal destruction were identified. These potential waste generators were then contacted to determine their willingness to supply sufficient quantities of each selected waste stream for thermal destruction testing in Phase II. Included in the following subsections are:

- Discussion of the methodology for preliminary selection of hazardous waste streams
- Description of the waste classification system adopted
- Discussion of the development of waste quantity and hazard rating systems and their use in assigning waste priority ranking factors
- Prioritization of wastes by class
- Discussion of the results of contacts with waste sources and the development of a final prioritized list of 50 waste streams including waste properties and potential sources.

3.1.1 Preliminary Waste Selection Methodology

An initial task in the waste prioritization process was the compilation of a list of additional hazardous waste streams by utilizing the existing TRW/ADL hazardous waste data base and the information generated by the contractors in the EPA Industry Waste Studies. These additional waste streams were selected on the basis of the following considerations:

- Feasibility of thermal destruction
- Potential health and environmental effects

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*A preliminary list of 34 potentially hazardous wastes was provided by EPA-OSWMP in the Statement of Work for Contract No. 68-01-2966, pp. 2-5.

- Representative combustion characteristics
- Volume of waste generated.

Using the above guidelines, most inorganic wastes were not considered as candidates for incineration tests. Furthermore, the hazard rating system described in Section 3.1.3 was used as a screening model, and a minimum hazard rating of 1 was the prerequisite for qualifying a waste stream under consideration as hazardous. For wastes having similar properties and belonging to the same chemical class, only one waste stream representative of the class of compounds was normally selected to minimize duplication of effort in incineration tests. For example, malathion waste was selected to represent the family of organophosphorus pesticide wastes, such as off-specification parathion and methyl parathion, all of which are hazardous and suitable for thermal destruction. In essence, they are expected to behave similarly upon thermal destruction.

As the list of additional waste streams was compiled, data concerning the generation source and location of the waste stream, annual quantity of waste generated, the physical form and chemical composition of the waste and the type of hazard associated with the waste were assembled. This information was then used as a screening tool to eliminate from further consideration waste streams that were not produced in sizable quantities, were not suitable for thermal destruction, or did not meet the minimum hazard rating. The waste streams added to the 34 listed by EPA included production wastes from refineries, ammunition plants, pesticide manufacturers, and chemical and petrochemical manufacturers. The information on the chemical characteristics and constituents, nature and degree of hazard, and the annual waste quantity for all the 97 waste streams, as well as the sources of this information, are presented with the discussion on waste prioritization by class in Section 3.1.4.

3.1.2 Waste Classification

Under equilibrium conditions, the products of thermal destruction are completely determined by the composition of the feed, and the temperature and pressure of the combustion chammber. In most thermal destruction tests, conditions are sought which will lead to complete combustion. Insofar as complete combustion is technically feasible, the end products will be simply related to the elemental composition of the waste stream. Thus any waste stream which consists entirely of hydrocarbons and/or hydrogen-carbon-oxygen components will yield only carbon dioxide and water vapor on complete combustion. Whether or nct complete combustion is achievable under the operating conditions of a commercial thermal destruction unit (temperature, pressure, feed rates, residence times, etc.) depends upon the specific physical and chemical properties of the waste stream.

In classifying wastes for thermal destruction testing, it is convenient first to categorize them on the basis of their elemental composition or products of complete combustion. Within each class of compounds with the same elemental composition, subclasses may be developed based on properties (e.g., physical form, chemical composition, Btu content, viscosity, etc.) which are related to the kinetics of combustion or the specific burning characteristics. Examination of available lists of waste streams (TRW, Battelle, ADL, Booz-Allen, and the EPA Report to Congress) shows that approximately 75 percent of those suitable for thermal destruction (primarily organics) fall into one of three classes:

- C-H and C-H-O compounds, yielding CO_2 and H_2O on complete combustion
- C-H-N and C-H-O-N compounds, yielding CO_2, H_2O and nitrogen oxides
- C-H-Cl and C-H-O-Cl compounds, yielding CO_2, H_2O and HCl (gas).

Within each class, of course, liquids may degrade differently from solids; an aliphatic amine may behave differently from an aromatic isocyanate; a high Btu content waste stream with a 99 percent hydrocarbon content may have different combustion characterisitcs than a low Btu content waste stream with 10 percent hydrocarbons and 90 percent water.

Typical waste streams in each of the above three major classes are listed in Table 3-3. Other potentially combustible waste streams are also listed by subclass in this table.

The classification of waste streams by elemental composition, also illustrated in Table 3-3, provides a useful guide to the selection of wastes for thermal destruction testing in Phase II. There are at least as many hazardous wastes as the number of hazardous organic chemicals produced commercially. Thus, it is estimated that there are over 10,000 potentially combustible waste streams well suited for incineration. Since only about 50 of these waste streams can be selected for full scale test in Phase II, there is a clear advantage in selecting the group of 50 to be as representative as possible of the range of thermal destruction characteristics likely to be encountered in practice. The recognition that waste streams of the same elemental composition should yield the same products on complete combustion provides an important basis for waste selection. The simple waste classification system presented also provides a basis for substitution of a lower priority waste for a higher priority waste (in the sense described in Section 3.1.4), when the latter may not be available for inclusion under this program.

3.1.3 Hazard/Volume Ranking Factor

A very simple model was developed for prioritizing the multitude of industrial processing waste streams which represent potential hazards for land disposal and for which thermal destruction appears to be a suitable alternative. In the development of the priority ranking model, two factors were taken into consideration: (1) the degree of hazard posed by the waste stream in land disposal, and (2) the quantity of waste generated and requiring disposal. The two factors were considered to be of equal importance in establishing priorities; i.e., a highly toxic or hazardous waste generated in relatively small quanitities appeared to merit approximately as much attention as a moderately toxic or hazardous waste generated in relatively large quantities. The simplest mathematical relationship that expresses this type of priority ranking for hazard and quantity factors r_f and Q respectively, is the product function:

$$PR = r_f Q \qquad (3\text{-}1)$$

where PR is a numerical ranking factor. The methodology adopted for assigning values to r and Q is described in the following paragraphs.

Hazard Rating

A given waste stream may be classified as hazardous by virtue of any number of factors. It may be subject to bioconcentration. It may be flammable and represent a potential fire hazard in land disposal. It may react violently with water or air, or even with itself. It may present an inhalation or dermal (skin contact) toxicity hazard. It may be toxic to aquatic life if leachate from a landfill reaches surface waters. It may represent a carcinogenic, mutagenic, or teratogenic hazard if permitted to enter the biosphere.

In general, there will be more than one reason for rating any single waste stream as potentially hazardous. The same waste stream, for example, might be known to produce cancer in rats, and also have a low oral LD_{50} value. The National Academy of Sciences-National Research Council, faced with a similar problem in evaluating potential hazards of industrial chemicals, concluded that it was only possible to rank with respect to each particular phase of the total hazard, considered by itself. They caution, "Any attempt to use mathematical operations to produce an index or composite in the form of one number should be discouraged, since such oversimplification can produce confusion and misunderstanding".(1)

For the purposes of this program, the hazard factor, r_f, in Equation (3-1) was calculated on the basis of the "worst" potential hazard presented by any major constituent of the waste stream (where a "major" constituent is one present at concentrations of 1 percent or more). Numerical values of r_f were assigned with reference to Table 3-1, in the following manner. If the waste stream (or major constituent of that waste stream) is known to be carcinogenic, mutagenic, or teratogenic, or to bioaccumulate in the food chain, r_f is taken as equal to 1000 (highest hazard rating). If the waste stream is not known to fall into these catagories (Hazard Categories 1, 8, 9 or 10 shown in Table 3-1), data are next assembled on flammability, reactivity, oral toxicity, inhalation toxicity, dermal toxicity, and aquatic toxicity for the waste stream or, more usually, its major constituents. The waste stream is then assigned the highest r_f value justified by any of the data (hence, r_f will be referred to as r_{max}). Thus, a waste stream with an oral LD_{50} of 20 mg/kg, an inhalation LC_{50} of 500 ppm, a TL_m of 30 mg/l, and is a lachrymator, would be assigned $r_{max} = 100$ on the

Table 3-1. Hazard Rating System

Hazard Category	Hazard Ratings (r_f)			
	1000	100	10	1
1. Bioaccumulation	Bioaccumulated and liable to produce a hazard to aquatic life or human health			Not known to be significantly bioaccumulated
2. Flammability	FP <100°F BP <100°F	FP <100°F BP >100°F	100°F < FP < 140°F	FP >140°F
3. Reactivity	Detonators Explosives	React explosively with water	Unstable exothermic materials or react violently with water	Normally stable, but unstable at elevated temperature
4. Oral Toxicity	LD_{50} < 5 mg/kg	LD_{50} 5-50 mg/kg	LD_{50} 50-500 mg/kg	LD_{50} 500-5000 mg/kg
5. Inhalation Toxicity	$LC_{50} \le$ 50 ppm or $\le$0.5 mg/l or OSHA 1 ppm	LC_{50} 50-200 ppm or 0.5-2 mg/l or OSHA 1-10 ppm	LC_{50} 200-2000 ppm or OSHA 10-100ppm	OSHA 100-1000 ppm
6. Dermal Toxicity	$LD_{50} \le$ 20 mg/kg 24 hr skin contact	LD_{50} 20-200 mg/kg 24 hr skin contact	Corrosive to skin	Lachrymators
7. Aquatic Toxicity	TL_m<1 mg/l	TL_m 1-10 mg/l	TL_m 10-100 mg/l	TL_m 100-1000 mg/l
8. Teratogenicity	Known to be teratogenic			Not known to be teratogenic
9. Carcinogenicity	Known to be carcinogenic			Not known to be carcinogenic
10. Mutagenicity	Known to be mutagenic			Not known to be mutagenic

r_{max} is the highest value of r_f exhibited by the waste stream in any category.

basis of its oral toxicity. Obviously, where there are gaps in the data base (e.g., the potential carcinogenicity of a waste stream constituent may not be known), the hazard factor may not properly reflect its maximum hazard. This is inevitable in any rating system.

The hazard rating assignments in Table 3-1 were derived from the NAS-NRC report to DOT, "System for Evaluation of the Hazards of Bulk Water Transportation of Industrial Chemicals," February 1974. In that report, four hazard "grades" are defined, ranging from slightly hazardous to extremely hazardous. In Table 3-1, r values of 1, 10, 100 or 1000 have been assigned to NAS-NCR Grades 1, 2, 3 and 4 respectively.

Quantity Rating

The quantity factor, Q, in Equation (3-1) is meant to reflect the annual quantity of a particular waste stream generated for disposal. For most waste streams, however, quantity data are very sparse. Even when available they are of questionable reliability. The few data which are available range from greater than 100 million lb/yr to less than 1 million lb/yr of waste generated.

On the basis of these considerations, the quantity factor Q is assigned with the values listed in Table 3-2.

Table 3-2. Quantity Ratings (Q)

WASTE QUANTITY	Q
>100 M lb/yr	1000
10-100 M lb/yr	100
1-10 M lb/yr	10
<1 M lb/yr	1
No known waste	0

The average values of each waste quantity ranges vary by approximately one order of magnitude; therefore, Q values were assigned by factors of 10.

Calculation of Priority Categories

Since both r_{max} and Q may assume values of 1, 10, 100 or 1000, their product, PR can range from 1 to 10^6 in multiples of 10. The only exception to these cases is when no known waste quantity was found to be associated with the waste stream considered, so that Q assumed the value 0 with a resulting PR of 0. A series of eight priority categories have therefore been defined as follows:

$PR = Q \cdot r_{max}$	Priority Category
10^6	I
10^5	II
10^4	III
10^3	IV
10^2	V
10	VI
1	VII
0	VIII

3.1.4 Waste Prioritization by Class

As the preliminary list of hazardous waste streams contains more than the 50 that will be considered for Phase II testing, a system for prioritization of these wastes (as described in Section 3.1.3) was developed to provide a guideline for selection of the wastes. The ranking of the waste streams according to their prioritization category was accomplished by combining the hazard rating of each waste stream with the waste quantity rating.

Waste Quantity Estimates

Information on the quantities of wastes generated was provided by the EPA Industry Waste Studies and through three other principal reference sources: Monsanto's report, "Potential Pollutants from Petrochemical Processes," (EPA Contract No. 68-02-0226, Task No. 9), Union Carbide's report, "Industry Waste Survey of Union Carbide's Institute Plant", Vol. 1 and 2, and the International Research and Technology Corporation Report, "Industrial Chemicals Solid Waste Generation - The Significance of Process Change, Resource Recovery, and Improved Disposal", (EPA Contract No. 68-03-0138). These information sources were used to obtain a waste factor (lb waste/lb product) for most of the waste streams selected. The waste factors were then used in combination with the annual production of the chemicals to provide an estimate of the annual waste production. In the case of the petroleum refinery wastes, annual waste quantities were obtained directly from the Jacobs Engineering report, "Assessment of Industrial Hazardous Waste Practices: Petroleum Refining," (EPA Contract No. 68-01-2288). In the case of the off-specification chemical wastes, information on the waste quantity or waste factor was not available, and a waste factor of 0.005 pound waste per pound product was assumed in the estimation of the annual waste quantity. This waste factor is a resonable average value for most industrial chemical processes.

Hazard Rating Estimates

Prior to assigning a hazard rating to each waste stream, the characteristics and constituents of the waste streams must be specified. Information on the properties of the waste streams was provided by the same reference resources as those used in waste quantity estimates. In addition, a number of reference sources were used to obtain the toxicity, flammability and reactivity data of the hazardous components, including: The Toxic Substance List - 1974 Edition, U.S. Department of Health, Education, and Welfare; Sax's Dangerous Properties of Industrial Chemicals; the Fire Protection Guide on Hazardous Materials published by the National Fire Protection Association; The Merck Index of Chemicals and Drugs; Bailey & Swift's Pesticide Information and Safety Manual; the Water Quality Criteria Data Book, Volume 1 - Organic Chemical Pollution of Freshwater published by the Water Quality Office of EPA; the TRW Recommended Methods of Reduction, Neutralization, Recovery or Disposal of Hazardous Wastes reports for EPA; and the Chemical Hazard Response Information System - Chemical Data Sheets by ADL. Data from these sources were used to estimate the hazard properties of each of the 97 waste streams and to assign a hazard rating of 1, 10, 100 or 1000 to each waste stream based on the maximum hazard effect. The hazard ratings were then used in combination with waste quantity ratings for the computation of the waste ranking factors, leading subsequently to the classification of the waste streams into the appropriate prioritization categories. The estimated waste quantity, the corresponding waste quantity rating, the waste stream characteristics and constituents, the types of hazard, the hazard rating, and the associated prioritization category for each of the 97 waste streams are presented in Table 3-3.

Results of the waste prioritization by class indicate that chlorinated hydrocarbon wastes are generally assigned a higher hazard rating than the other classes of wastes, whereas the simple hydrocarbon wastes were found to be generated in larger quantities. Of the 97 waste streams ranked, only one waste stream - the dichloroethane and heavy chlorinated hydrocarbon containing waste from vinyl chloride monomer manufacture, was designated Prioritization Category I, because of both the potential carcinogenic hazard and the large volume of waste generated. The number of waste streams designated Prioritization Category II totals 4, and the number of waste streams designated Prioritization Category III totals 4. The majority of the ranked waste streams fall into either Prioritization Categories IV (31 waste streams) or V (24 waste streams). However, because of the uncertainties in both the hazard rating and the waste quantity estimates, as well as the simplicity of the priority ranking model utilized, the prioritization category designated for each waste stream should only be a guide and not the overriding consideration in the selection of waste streams for Phase II incineration tests.

3.1.5 Sources, Properties, and Selection of 50 Waste Streams

The generation sources and locations of the 97 waste streams preliminarily chosen were identified by the use of the SRI Directory of Chemical Products (1974) and the Synthetic Organic Chemical - United States Production and Sales, 1973 published by the United States Tariff Commission. The individual plants generating the waste streams of interest were then contacted by phone to determine their willingness in providing waste materials for Phase II thermal destruction tests. To each plant expressing an interest in the program, a follow-up letter was

Table 3-3. Waste Prioritization by Class

Waste Class 1: C-H and C-H-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category II					
**Ethylene glycol manufacturing wastes	Mixture of water and glycols	Toxic - oral	100	120	1,000
Prioritization Category III					
*Off-specification isoprene ✓	Unstable oxidizable liquid containing isoprene	Flammable	1,000	1-10	10
*Off-specification phenol ✓	90 to 92% or 82 to 84% phenol containing some cresols and water	Toxic - oral, dermal, aquatic	100	10-100	100
Prioritization Category IV					
Off-specification organic peroxides	50 to 75% organic peroxides (e.g., benzoyl peroxide) in water or organic solvent	Explosive	1,000	0.04	
*Evaporator residue from the cumene process for phenol manufacture ✓	Polymeric matter containing acetophenone (1.68 wt %), phenol (0.66 wt %), and cumylphenol (0.75 wt %)	Toxic - oral, dermal, aquatic	1	223	1,000
**API separator bottoms from petroleum refineries	Sludge containing water and benzene soluble organics (30 to 50 wt %), approximately 10 to 50 PPM vanadium, and PPM levels of heavy metals	Toxic - aquatic	1	138	1,000

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 1: C-H and C-H-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category IV (Continued)					
**Dissolved air flotation float from petroleum refineries	Sludge containing water and benzene soluble organics (20 to 80 wt %), approximately 10 PPM vanadium, and PPM levels of heavy metals	Toxic - aquatic	1	120	1,000
*Lime sludge from acetylene production by the carbide method	Sludge containing mostly calcium hydroxide, some water and traces of organics such as benzene	Toxic - aquatic, oral	1	1,178	1,000
*Waste residues from alkyl benzene production ✓	Liquid containing alkyl benzene, paraffins, benzene (5%), and possibly some chlorobenzenes and tar.	Toxic - oral, inhalation, aquatic	1	103	1,000
**Tars from production of styrene ✓	Polymeric tar containing styrene and ethylbenzene	Toxic - oral, inhalation, aquatic	1	165	1,000
**Rubber manufacture waste sludge ✓	Solid waste containing SBR rubber (styrene-butadiene copolymer) and carbon black plus the usual salts, fatty acids, scrap, etc., from the coagulation of latex	Toxic - aquatic	1	10-100	1,000
Prioritization Category V					
**Isophthalic acid and terephthalic acid still bottoms ✓	Mixture of phthalic acid (38%), toluic acid (11%), benzoic acid (18%), trimellitic acid (8%), aldehydes (11%), acetic acid (2%), high boilers (5%), bromine (1%), manganese (1%), cobalt (2%)	Toxic - oral, aquatic	1	11	100

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 1: C-H and C-H-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category V (Continued)					
**Ethylene manufacturing wastes ✓	Water separable oil containing heavy polymeric oils with traces of aromatics	Toxic - oral, aquatic	1	33	100
**Petroleum polymer resin wastes	Lime-clay mixtures with solvents and resins, 55-65% solids (Attapulgus clay and hydrated lime); liquid phase-polyoils with 15-25% resin yield; BF_3 contamination	Toxic - oral, aquatic	1	92	100
*Resin wastes from the manufacture of phenolic and alkyd resins; off-spec resins	Mixture of phenol-formaldehyde, phthalic anhydride, polyester and styrene-polyester resins	Toxic - oral, aquatic	1	10-100	100
*Acrylic acid manufacturing wastes (aqueous emulsions of acrylic acid)	Heavy ends from acrylic acid finishing system containing acrylic acid (11.3 wt %), polymers (58.5 wt %), hydroquinone (30.2 wt %), and some water	Toxic - oral, inhalation, dermal	10	5	10
**Organic peroxide manufacturing wastes (from dicumyl peroxide manufacture) ✓	Organic waste stream containing dicumyl peroxide and other aromatic diacyl peroxides in a mixture of alcohols, phenols, cumene alcohol derivatives and other unknown reaction by-products	Toxic - oral, inhalation, dermal, aquatic	10	2	10
**Cooling water separation sludge from petroleum refineries	Sludge containing water and benzene soluble organics (30 to 60 wt %), approximately 20 PPM vanadium, and PPM levels of heavy metals	Toxic - aquatic	1	76	100
**Slop oil tank emulsion waste from petroleum refineries	Emulsion containing water and benzene soluble organics (20 to 60 wt %), approximately 10 to 100 PPM vanadium, and PPM levels of heavy metals	Toxic - aquatic	1	68	100

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 1: C-H and C-H-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category V (Continued)					
*Tars from production of phthalic anhydride (xylene process) ✓	Tars containing phthalic anhydride (78 wt %) and maleic anhydride (22 wt%)	Toxic - oral, dermal, aquatic	1	11	100
*Still bottom from acetaldehyde production and by-product recovery operation ✓	Liquids containing various aldehydes	Toxic - oral, inhalation, aquatic	1	23	100
Prioritization Category VI					
*Tars from the production of phthalic anhydride (naphthalene process)	Tars containing phthalic anhydride (58 wt %)	Toxic - oral, dermal, aquatic	1	9	10
*Maleic anhydride manufacture still bottoms	Sludge containing maleic anhydride (12%) and high boilers such as tar, fumaric acid, chromogenic compounds	Toxic - oral	1	9	10
Off-specification maleic anhydride	Maleic anhydride flakes, pellets, rods, briquettes, or solidified in container	Toxic - oral	1	2	10
Prioritization Category VII					
*Waste from tetrahydrobenzaldehyde manufacturing	Slurry wastes containing tetrahydrobenzaldehyde (50 to 60 wt %)	Toxic - oral, dermal, aquatic	1	0.8	1

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 1: C-H and C-H-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category VII (Continued)					
**Miscellaneous organic pesticides (Pyrethins)	High molecular weight alcohols and esters as well as Xanthophylls. The Xanthophyll fraction contains carotene	Toxic - oral	1	<1	1
Prioritization Category VIII					
Acrolein manufacturing wastes	Only known source of acrolein manufacturing waste appears to be the propylene absorber off-gas containing propylene, propane and carbon monoxide			0	0
Petroleum refining aldehyde wastes	Waste contains acetaldehyde, butyl aldehyde, formaldehyde and furfural	Toxic - oral, inhalation, dermal, aquatic		Negligible quantity	0

**Affirmative letter received

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 2: H-C-N and H-C-N-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category II					
*Red water from TNT manufacture	Typical composition is 5 to 35% solid content consisting of TNT isomers, TNT intermediates and sulfite and sulfate salts. Ash from incineration contains about 80% sodium carbonate and about 5% sodium sulfite and other inorganics	Toxic - aquatic	100	250 (based on solids content of 35 wt %)	1,000
*Explosive/propellant wastes from ammunition plants	Scrap explosives and propellants including RDX (cyclomethylene trinitroamine), HMX (cyclotetramethylene tetranitroamine), nitroglycerin, nitrocellulose, etc.	Explosive	1,000	23	100
Prioritization Category IV					
HCN production wastes	Aqueous wastes containing sulfuric acid and 0.2% HCN	Toxic - aquatic, oral	1	>100	1,000
*Carbamate pesticides (Carbaryl) ✓	Naphthol residues containing approximately 1% b-naphthol	Toxic - oral	10	18	100
Jet fuel wastes; hydrazine manufacture	Liquid fuel containing hydrazine	Explosive	1,000	<1	1
Rubber industry wastes containing nitrobenzene	Wastes containing nitrobenzene or off-specification nitrobenzene	Toxic - oral	100	1-10	10
*Reactor tar bottoms from adiponitrile manufacture ✓	Tars containing phosphoric acid (4.8 wt %) and adiponitrile	Toxic - oral, inhalation, aquatic	10	96	100

*Affirmative responses by telephone
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 2: H-C-N and H-C-N-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category IV (Continued)					
Contaminated tetranitromethane	Tetranitromethane	Explosive	1,000	<1	1
**Solid residue from manufacture of aromatic amines ✓	Long chain aromatic amines	Toxic - oral	10	20	100
**Catch basin grease nitrile pitch from production of surface active agents ✓	Fatty alkyl acids, nitriles and amines (C-8 to C-18 carbon chain length), water (20%)	Toxic - oral, aquatic	10	20	100
**Steam still bottoms from aniline and alkylated phenol manufacture ✓	Mixture of phenolic compounds and aniline derivatives	Toxic - oral, dermal, inhalation, aquatic	10	50	100
Prioritization Category V					
*Acrylonitrile manufacturing wastes ✓	Heavy ends containing acrylonitrile ($CH_2 = CHCN$), acetonitrile (CH_3CN), HCN and probably polymeric material	Toxic - oral, inhalation, aquatic	10	3	10
**TDI manufacture reactor tar bottoms ✓	Wastes in tar are cyclic biureates and a complex mixture of heavy organics; no analysis available. However, effluent gas from incinerator has the following composition: CO_2, 33.3%; H_2O, 26%; N_2, 38.8%; O_2, 5%; HCl, small amounts	Toxic - inhalation	10	9	10

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 2: H-C-N and H-C-N-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category V (Continued)					
**Alkyl amine still bottoms	Distillation residue containing C-8 to C-18 carbon	Toxic - oral	10	4	10
**Dimethyl alkyl amine still bottoms	Distillation residue containing C-8 to C-18 carbon	Toxic - oral	10	2	10
**Diphenylamine (DPA) manufacture reactor tar bottoms ✓	Tars containing cyclic biureates (50%) and heavy organics (50%)	Toxic - oral, dermal, inhalation	10	4	10
*Isocyanate recovery section bottoms from MDI (methylene diphenyl diisocyanate) manufacture	Tars containing MDA (4,4"-methylene-dianiline), unreacted aniline and formaldehyde, and MDI	Toxic - oral, inhalation, dermal, aquatic	1	22	100
*Waste from toluenediamine (TDA) production from dinitrotoluene (DNT) ✓	Refining still residue containing TDA and other isomers of TDA	Toxic - oral	10	6	10
*DNT/MNT mix waste from DNT production ✓	Sludge containing nitrotoluene (MNT), dinitrotoluene (DNT) and possibly trinitrotoluene (TNT) and other organic solids	Toxic - oral, inhalation, dermal, aquatic Potentially explosive	10	2	10
*Dinitrophenol wastes ✓	Still bottom residue from dyestuff intermediates	Toxic - oral, inhalation, dermal	100	<1	1

*Affirmative responses by telephone
**Affirmative letter received
✓ Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 2: N-C-N and H-C-N-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category VI					
**Phenylamine tar wastes √	Tars containing aniline (30%), nitrobenzene (5%), cyclic biureates (33%), and heavy organics (32%)	Toxic - oral, inhalation	1	6	10
*Wastes from polymer polyol production from polymerization of styrene with acrylonitrile √	Liquid containing unreacted styrene and acrylonitrile	Toxic - oral, inhalation, dermal, aquatic	10	0.4	1
Prioritization Category VII					
s-traizine (Atrazine)	Wettable powder containing 50% Atrazine	Toxic - oral	1	<1	1
Prioritization Category VIII					
Off-specification toluene diisocyanate	Mixture of 65-35% or 80-20% 2,4 and 2,6 isomers of TDI	Toxic - inhalation	10	No known waste	0

*Affirmative responses by telephone
**Affirmative letter received
√Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 3: H-C-Cl and H-C-Cl-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category I					
**Vinyl chloride monomer manufacturing wastes ✓	Dichloriethane and heavy chlorinated hydrocarbon wastes containing vinyl chloride	Carcinogenic	1,000	162	1,000
Prioritization Category II					
*Organic chemical, capacitor, transformer, production wastes containing PCB's and alpha methylstyrene ✓	Waste containing PCB's and alpha methylstyrene, in capacitors	Carcinogenic	1,000	22	100
Prioritization Category III					
*Reactor bottoms from PVC manufacture ✓	PVC resins containing 100 to 3000 PPM vinyl chloride monomer	Carcinogenic	1,000	5	10
Prioritization Category IV					
**Epichlorohydrin manufacturing wastes ✓	Heavy ends from fractionation column containing dichlorohydrin, epichlorohydrin, allyl chloride, and polymeric material	Toxic - oral, inhalation, dermal, aquatic	10	26	100
*Heavy bottoms from purification column in ethylene dichloride manufacture	Sludge containing ethylene dichloride (22.8 wt %), 1,1,2-trichloroethane (38.2 wt %), tetrachloroethane (38.2 wt %) and traces of tar	Toxic - oral, dermal, inhalation, aquatic	10	49	100

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 3: H-C-Cl and H-C-Cl-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category IV (Continued)					
*Tars from propylene oxide production by the chlorohydrin process	Heavy ends containing tar, propylene chlorohydrin, propylene glycol and propylene oxide	Toxic - oral, inhlation, aquatic	10	53	100
*Hexachlorocyclobutadiene manufacturing wastes √	Mixture of chlorinated toluenes, pentanes, and benzenes	Toxic - oral, dermal, inhalation, aquatic	10	10-100	100
**Still bottoms from perchloroethylene production √	Still bottoms containing perchloroethylene, carbon tetrachloride, hydrocarbons, and other chlorinated hydrocarbons	Toxic - oral, inhalation	10	24	100
Prioritization Category V					
**Phenolic tar from 2,4-D manufacture √	Typical composition: 2,4-dichlorophenol (8%), 2,6-dichlorophenol (2%), 2,4,6-trichlorophenol (35%), phenolic resins (55%)	Toxic - aquatic, oral	10	1.3	10
Prioritization Category VI					
**Organic pharmaceutical wastes √	Liquid wastes containing mixture of organics such as phosgene, chlorobenzene, toluene, methanol, methylene dichloride, tetrachlorethane, in chloroethylene	Toxic - oral, aquatic	10	<1	1
*Chlorotoluene production wastes √	Tars containing benzoyl chloride residues	Toxic - oral, inhalation, dermal	10	<1	1
*Tars and organics from batch organic processes	Tars containing heavy organics and chlorinated organics	Toxic - oral	10	<1	1

*Affirmative responses by telephone
**Affirmative letter received
√ Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 3: H-C-Cl and H-C-Cl-O Compounds

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category VII					
**Phenolic tar from MCPA manufacture ✓	Typical composition: 4-MCPA (20%); 6-MCPA (20%), phenolic resins (60%)	Toxic - oral, aquatic	1	0.1	1
Chlorinated aliphatic herbicides (Dalapon)	Sodium salt of Dalapon in granular or powder form	Toxic - oral	1	<1	1
Prioritization Category VIII					
Chlorinated hydrocarbon pesticides (Aldrin)				Aldrin production discontinued	0
Spent wood preserving liquid containing pentachlorophenol	Pentachlorophenol liquid	Toxic - oral, inhalation, dermal	100	Negligible quantity	0

**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Nitrogen and Chlorine Containing Wastes					
Prioritization Category IV					
*Nitrochlorobenzene manufacturing wastes ✓	Heavy ends and tars from orthochloronitrobenzene vacuum distillation	Toxic - oral	10	20	100
*Amiben manufacturing wastes ✓	Liquid containing 90% water, 5% isomers of Amiben and 5% NaCl and Na_2SO_4	Toxic - oral	1	>100	1,000
Prioritization Category V					
**Fatty quaternary chloride skimmings	C-8 to C-18 chain length, 90-98% water	Toxic - oral	10	1-10	10
Prioritization Category VI					
*Dichloroaniline still bottoms ✓	Mixture of isomers; 25% chlorine content	Toxic - oral	10	<1	1
Prioritization Category VII					
Phenylurea herbicides (Diuron)	Tars containing Diuron	Toxic - oral	1	<1	1

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Nitrogen, Chlorine and Sulfur Containing Wastes Prioritization Category VII					
Carboximate fungicides (Caftan)	Tars containing Caftan from Caftan manufacture	Toxic - oral	1	<1	1
Sulfur Containing Wastes Prioritization Category IV					
Dimethyl sulfate production still bottoms	Viscous dark brown liquid residue containing 0.1 to 1% dimethyl sulfate and dimethyl ether	Flammable, toxic - oral, inhalation, dermal	1,000	0.1	1
Alkylation sludge containing sulfuric acid from petroleum refineries	Sludge containing sulfuric acid, polymerized hydrocarbons, and tank scale, etc.	Toxic - oral, inhalation, dermal	1	>100	1,000
**Petroleum refining sour wastes ✓	Waste contains sodium sulfides, H_2S, ammonium sulfide, phenol, mercaptans, acetic acid, cyanides, and nitrogen bases	Toxic - aquatic	1	>100	1,000
Prioritization Category VI					
*Alkyl and aryl sulfonic acid manufacturing wastes ✓	Emulsified oil and sulfones	Toxic - oral	1	1-10	10

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category VI (Continued)					
**Benzothiophene manufacture waste sludge	Mixture of olefins, thiophene, polymers, sulfonated aromatics, sodium salts, organics and salts (60% H_2SO_4 + 40% inorganics)	Toxic - oral	10	<1	1
Prioritization Category VII					
**Mercaptobenzothiazole (MBT) manufacturing wastes ✓	Tarry mixture of 75% organic sulfur containing heterocyclics, 15% sulfur and 10% water	Toxic - oral, dermal	1	<1	1
**Dodecyl mercaptan manufacturing wastes ✓	High viscosity liquid	Reactive, Toxic - inhalation	1	<1	1
Fluorine Containing Wastes Prioritization Category VII					
Trifluralin manufacturing wastes	Information unavailable	Toxic - oral	1	<1	1
*Fluorinated herbicide wastes ✓	Liquid containing aromatic fluorides	Toxic - oral	1	< 1	1

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
	Bromine Containing Wastes Prioritization Category V				
**Halogenated aliphatic fumigants (ethylene bromide) ✓	Mixture of brominated organic liquids containing 10-20% dibromopropanol from ethylene bromide manufacture	Toxic - oral, dermal, inhalation	10	8	10
	Phosphorous Containing Wastes Prioritization Category VI				
*Organophosphorus pesticides (malathion) ✓	Off-specification technical grade malathion	Toxic - oral, inhalation, dermal, aquatic	10	0.15	1
	Prioritization Category VII				
*Still bottoms from the manufacture of Rabon [2-chloro-1-(2,4-5-trichlorophenol) vinyl dimethyl phosphate][1]	Heavy ends from the manufacture of Rabon intermediate are believed to contain dichloroacetyl chloride in trichloroethylene. Heavy ends from hexane recovery are believed to contain pentachloroacetophenone, trimethyl phosphate, crude product and by-product, all dissolved in hexane.	Toxic - oral, inhalation, dermal, aquatic	1	0.16	1

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

[1] Operation has been temporarily shut down; availability of waste questionable

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
	Prioritization Category VII (Continued)				
*Urethane manufacturing wastes ✓	Mixture of polyols and phosphate esters	Toxic - oral	1	<1	1
	Silicon Containing Wastes Prioritization Category VI				
**Tetraethyl orthosilicate wastes ✓	Tetraethyl orthosilicate liquid with traces of iodine, alcohol and "Genesolu" D	Toxic - inhalation	10	<1	1
	Wastes Containing Mixtures of Sodium Salts or Caustic and Organics Prioritization Category III				
*Neutralized acid waste from the manufacture of methyl methacrylate	Sludge containing methanol (0.4%), polymers (0.2%), ammonia (0.34%), ammonium acetate (0.03%), ammonium cyanide (0.65%), ammonium methacrylate (0.60%), ammonium sulfate (94.34%), and sodium sulfate (3.38%)	Toxic - oral, inhalation, aquatic	10	2,520	1,000
	Prioritization Category IV				
**Refinery spent caustic ✓	Typical composition: Total Na^+ (1.45 wt %), total sulfur (2.58 wt %), water (81.0 wt %), other (11.97 wt %). Spent caustic solutions contain sulfides, mercaptides, sulfates, sulfonates, phenolates, naphthenates, and other similar organic and inorganic compounds	Toxic - oral, dermal	1	44,000	1,000

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
Prioritization Category IV (Continued)					
**Coke plant wastes ✓	Weak ammonia liquor containing phenols, cyanides, chlorides, sulfates and total dissolved solid content of approximately 6000 mg/l	Toxic - aquatic	1	>100	1,000
**Paper mill cooker liquor	Waste containing 94% water, 3.5% organic, 2.4% inorganic; high COD; pH = 13.0	Toxic - aquatic	1	>100	1,000
Prioritization Category V					
**Epoxy resin (condensation of bisphenol-a and epichlorohydrin) manufacture reactor bottoms	Typical composition: methyl isobutyl ketone (10.7 wt %), sodium chloride (81.8 wt%), sodium monohydrogen phosphate (4.0 wt%), epichlorohydrin methanol by-product (3.5 wt %)	Toxic - oral, inhalation, dermal, aquatic	1	99	100
**Mixed imide, formate, and glycine processing wastes	10% organic/90% aqueous stream; high in chloride salts, contains traces of phenol, EDC, DMA, n-ethyl aniline, toluene, and methanol	Toxic - aquatic, oral	1	12	100
Prioritization Category VII					
*Dyestuff manufacturing wastes	Waste containing 8-10% NaCl, 2% Na_2SO_4, heavy metals and organics	Toxic - oral, aquatic	1	<1	1

*Affirmative responses by telephone
**Affirmative letter received
✓Wastes selected for Phase II testing

Table 3-3. Waste Prioritization by Class (Continued)

Waste Class 4: Other Wastes

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Type of Hazard	Hazard Rating r_{max}	Volume of Waste Generated M lb/year	Waste Quantity Rating Q
	Wastes Containing Mixtures of Metals and Organics Prioritization Category IV				
*Cyanide wastes from plating operations	Aqueous waste containing typically 30 PPM cyanide, 10 PPM chromium, 20 PPM copper, 5 PPM zinc, 1 PPM cadmium, 2 PPM iron and 30 PPM nickel	Toxic - aquatic, oral	1	710,000	1,000
	Prioritization Category VII				
**Settled sludge from clarification of wastewaters in the manufacture of paint additives (heavy metal/organics)	Sludge containing aliphatic hydrocarbons (mineral spirits, kerosene, etc.) and driers such as the naphthenates, octoates, linoleates, tallates and 2-ethylhexanoates of calcium, cobalt, lead, manganese and zirconium, with approximately 60 to 70% solids content	Toxic - oral, aquatic	1	0.14	1

*Affirmative responses by telephone
**Affirmative letter received

sent, stating clearly the objectives of the EPA/TRW/ADL program and requesting additional information on the characteristics of the waste streams. Of the more than 130 waste sources contacted, approximately 54 percent indicated willingness to cooperate, 11 percent expressed some doubt about participating, and 35 percent have declined to participate. The various reasons given for declining to participate include the following:

- Wastes generated at the plant are currently being satisfactorily incinerated; do not see need for further study.
- Plant is now on full recycle and no waste is being generated.
- Production of the chemical has been discontinued, and hence the waste stream requested is no longer being generated.
- The manufacturing process of interest has no solid or concentrated liquid waste generation.
- Waste generated at the plant is used as feedstock for another plant.
- Manufacturing process is proprietary and waste stream analysis would lead to the disclosure of proprietary information.
- Not interested in supplying the waste streams requested.

Many companies willing to cooperate expressed enthusiasm for the program for the following reasons:

- Alternative methods have proven less than satisfactory, and information on incineration is desired.
- Incineration has been tried, but the results are not as conclusive as had been hoped.
- Waste streams have presented a real problem for disposal, and while incineration seems to be an acceptable alternative to present methods, additional data are desired before investing in an incineration facility.

In addition, it should be noted that of the waste sources that are willing to cooperate, some of the waste streams originally requested are no longer available, and alternate waste streams have been suggested. Often, the alternate waste streams: appeared to be suitable for disposal by incineration; presented a significant hazard to the environment; and were produced in sufficient quantities to warrant a high prioritization category designation. In cases where these criteria were met, the alternate waste streams were considered.

The selection of the final 50 waste streams for Phase II incineration tests was based on the following considerations:

- Prioritization category designation for the waste stream within the waste class
- Availability of the waste stream
- Unavailability of existing, economical, and environmentally acceptable methods for the disposal of the waste stream
- Feasibility or suitability of destroying the waste stream by thermal degradation.

Of the 97 waste streams listed in Table 3-3, 47 waste streams have been eliminated to give the final list of 50 waste streams selected for Phase II tests as a result of the above considerations. The basic rationale for eliminating the majority of the 47 waste streams can be delineated as follows:

Wastes that are not available. Off-specification organic peroxides, jet fuel wastes, hydrazine manufacturing wastes, off-specification maleic anhydride, acrolein manufacturing wastes, petroleum refinery aldehyde wastes, spent wood preserving lqiuid, Dalapon, dimethyl sulfate production still bottoms, Trifluralin, contaminated tetranitromethane, and rubber industry wastes containing nitrobenzene. Since these wastes are either of low priority, or can be adequately substituted by wastes expected to have similar degradation characteristics, there appears to be no further need to locate potential sources.

Low priority (prioritization category V, VI, VII or VIII) wastes. Reference to Table 3-3 will show that some of the lower priority wastes were selected either as substitutes with similar characteristics to higher priority wastes that were unavailable, or because they were representative of an important class of compounds.

Wastes not suitable for incineration (because of high inorganic content). Lime sludge from acetylene production by the carbide method; neutralized acid waste from the manufacture of methyl methacrylate (ammonium sulfate recovery should be considered instead); alkylation sludge containing sulfuric acid from petroleum refineries; settled sludge from clarification of wastewaters in the manufacture of paint additives; and lime clay mixtures with absorbed solvents and resins.

Wastes requiring pretreatment prior to incineration and currently being adequately handled commercially. HCN production wastes; cyanide wastes from plating, and paper mill sulfite cooking liquor.

In addition, when a number of wastes of equal priority were in the same chemical class and were expected to have similar degradation characteristics, only one representative waste was generally selected. The 50 waste streams selected are marked with a check (✓) in Table 3-3.

In addition to the basic rationale for waste selection and elimination described above, there are other specific reasons for inclusion or exclusion of a waste stream on the final 50 list. For each of the three major classes of waste stream [H-C-(O); H-C-N-(O), and H-C-Cl-(O)], wastes in the highest prioritization categories were selected, with the following exceptions:

H-C-(O) Wastes

- Priority IV off-specification organic peroxide wastes were unavailable, and Priority V organic peroxide manufacturing wastes were substituted.
- Both API separator bottoms and dissolved air flotation floats from petroleum refineries (Priority IV) are approximately similar in composition and properties. Only the API separator wastes were selected.
- The lime sludge from acetylene production (Priority IV) is primarily calcium hydroxide and not well suited for incineration.
- Four additional wastes were selected from Priority V, the phthalic anhydride tars because of their resource recovery potential; the acetaldehyde still bottoms and ethylene cracking wastes to increase the number of available liquid wastes tested; and the isophthalic-terephthalic acid still bottoms because they are among the few non-tarry solid wastes believed suitable for multiple hearth.

H-C-N-(O) Wastes

- Both of the Priority II wastes were eliminated because they are produced almost exclusively for the Armed Services. (The purpose of this program is to study commercial wastes.)
- Priority IV wastes not selected include: HCN production waste which is an aqueous waste stream and is being adequately handled commercially; jet fuel waste which is not available; hydrazine manufacturing wastes which seem to have been eliminated in current production methods.
- Priority V wastes not selected include: MDI bottoms which should be similar in destruction characteristics to TDI and DPA wastes, the availability of both of which has been confirmed by letter; and two of the three similar alkyl amine type still bottom streams.

H-C-Cl-(O) Wastes

- In Priority IV, the chlorohydrin process wastes were eliminated because of their similarity to the epichlorohydrin manufacturing wastes whose availability has been confirmed by letter; ethylene dichloride bottoms were eliminated because they are very similar to the perchloroethylene still bottoms selected.
- In Priority VI, mixed tars and sludge from batch processes were eliminated because of the extremely difficult analytical problems presented, and the negligible amount of information to be obtained as compared to available and better characterized tars and sludges.
- In Priority VII, only the available phenolic tar was selected. Due to the low priority and lack of availability, Dalapon was eliminated.

Most of the waste streams classed "Other" are of relatively low priority. In order to provide information on a representative range of wastes for which incineration may be a viable disposal alternative, several of these wastes were selected as indicated in Tables 3-3 and 3-4. Priority was a major consideration, except as noted in Table 3-4. The wastes selected are representative of wastes containing both nitrogen and chlorine in addition to normal H-C-(O) components; sulfur containing wastes; fluorine containing wastes; bromine containing wastes; and finally organic wastes high in sodium content which are believed to present difficult problems in many incineration facilities, such as high corrosion and formation of fine particulates.

Table 3-4. Summary of Waste Streams Selected for Testing

Chemical Class	Number of Wastes	Priority	Physical Form	Comments on Waste Selection
H-C and H-C-(0)	1	II	1 liquid	
	2	III	1 liquid, 1 solid	
	5	IV	2 tars, 1 liquid, 2 sludges	See Text
	5	V	3 liquids, 1 tar, 1 solid	
Total	13		6 liquids, 2 sludges, 3 tars, 2 solids	
H-C-N and H-C-N-(0)	5	IV	1 liquid, 2 tars, 2 solid	
	6	V	3 tars, 1 sludge, 1 viscous liquid, 1 semi-solid	See Text
	2	VI	1 tar, 1 liquid	
Total	13		3 liquids, 1 sludge, 6 tars, 3 solids	

Table 3-4. Summary of Waste Streams Selected for Testing (Continued)

Chemical Class	Number of Wastes	Priority	Physical Form	Comments on Waste Selection
H-C-Cl and H-C-Cl-(O)	1	I	1 liquid	
	1	II	1 solid	See Text
	1	IV	1 solid	
	3	IV	2 liquids, 1 tar	
	1	V	1 tar	
	2	VI	1 liquid, 1 tar	See Text
	1	VII	1 tar	
Total	10		4 liquids, 4 tars, 2 solids	
Other Wastes				
A. N and Cl containing wastes	2	IV	1 liquid, 1 tar	Fatty quarternary chloride skimming waste has 90-98% water and not suitable candidate for incineration
	1	VI	1 solid	

Table 3-4. Summary of Waste Streams Selected for Testing (Continued)

Chemical Class	Number of Wastes	Priority	Physical Form	Comments on Waste Selection
B. Sulfur containing organics	1	VI	1 liquid	Dimethyl sulfate waste is unavailable; alkylation sludge is not suitable for incineration, benzothiophene sludge is not suitable for incineration
	2	VII	1 liquid, 1 tar	
C. Fluorine containing organics	1	VII	1 liquid	
D. Bromine containing organics	1	V	1 liquid	
E. Phosphorus containing organics	1	VI	1 liquid	
	1	VII	1 liquid	
F. Silicon containing organics	1	VI	1 liquid	
G. Mixture of organics and sodium salts or caustic	3	IV	3 liquids	Neutralized acid waste from methyl methacrylate manufacture not suitable for incineration
Total	14		11 liquids, 2 tars, 1 solid	

Table 3-5 gives for each of the selected waste streams descriptions of the physical and chemical characteristics, waste class and prioritization category, and potential waste sources and locations. The heating value for each waste stream has been denoted either high (10,000 to 15,000 Btu/lb), medium (5000 to 10,000 Btu/lb), or low (less than 5000 Btu/lb), as the Btu contents of most waste streams are not available at this point and only order of magnitude estimates can be provided. The names of the potential waste sources have been coded because of confidentiality agreements.

It is important to recognize that waste stream descriptions obtained from the literature, or supplied by a plant, cannot be considered reliable until an actual sample of the waste stream which is to be delivered has been obtained and analyzed. Still bottoms, for example, may be liquids or tars, depending upon the stage at which distillation is stopped. This, in turn, may be entirely at the discretion of the operator. When samples of the wastes described in this report are obtained during Phase II, it is expected that some will differ in properties from those described here. In those cases where these differences are significant, the methodology described herein provides guidance for seeking substitutes. In Table 3-3, waste streams marked with an asterisk (*) are generated by plants that have agreed orally to supply wastes; streams marked with a double asterisk (**) have been promised in writing. Experience with plants that did respond by letter to written follow-up requests indicates that waste streams described in the letter from the plant did not always correspond with the waste stream discussed in the preliminary telephone contact. Hence, neither the availability of the waste streams not the validity of the waste descriptions can be considered absolutely firm until letters have been received.

3.2 THERMAL DESTRUCTION FACILITIES

The major premise in the development of a list of thermal destruction facilities was to insure that broad spectra of various types of facilities were contacted and evaluated for their potential to destroy toxic and hazardous wastes. As a first step, the TRW/ADL team reviewed

Table 3-5. Hazardous Waste Properties and Sources

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Ethylene glycol manufacturing wastes	Mixture of water and glycols	Liquid	Low	1, II	1, La.
Off-specification isoprene	Unstable oxidizable liquid containing isoprene	Liquid	High	1, III	2, Texas
Off-specification phenol	90 to 92% or 82 to 84% phenol containing some cresols and water	Liquid	High	1, III	3A, Texas 3B, N.J.
Evaporator residue from the cumene process for phenol manufacture	Polymeric matter containing acetophenone (1.68 wt %), phenol (0.66 wt %), and cumylphenol (0.75 wt %)	Tar	Medium	1, IV	4A, Texas 4B, N.J.
API separator bottoms	Sludge containing water and benzene soluble organics (30 to 50 wt %), approximately 10 to 50 PPM vanadium, and PPM levels of heavy metals	Sludge	Medium	1, IV	Petroleum Refineries
Waste residues from alkyl benzene production	Liquid containing alkyl benzene, paraffins, benzene (5%), and possibly some chlorobenzenes and tar	Liquid	High	1, IV	6A, Texas 6B, W.Va.
Tars from production of styrene	Polymeric tar containing styrene and ethylbenzene	Tar	Medium	1, IV	7A, Texas 7B, Texas 7C, Texas 7D, La.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Rubber manufacturing waste sludge	Solid waste containing SBR rubber (styrene-butadiene copolymer) and carbon black plus the usual salts, fatty acids, soaps, etc., from the coagulation of latex	Solid	Medium	1, IV	8, Texas
Isophthalic acid and terephthalic acid still bottoms	Mixture of phthalic acid (38%), toluic acid (11%), benzoic acid (18%), trimellitic acid (8%), aldehydes (11%), acetic acid (2%), high boilers (5%), bromine (1%), manganese (4%), cobalt (2%)	Solid	Medium	1, V	9, Ill.
Ethylene manufacturing wastes	Water separable oil containing heavy polymeric oils with traces of aromatics	Liquid	High	1, V	10, La.
Organic peroxide manufacturing wastes (from dicumyl peroxide manufacture)	Organic waste stream containing dicumyl peroxide and other aromatic diacyl peroxides in a mixture of alcohols, phenols, cumene alcohol derivatives and other unknown reaction by-products	Liquid*	High	1, V	11, N.Y.
Tars from production of phthalic anhydride (xylene process)	Tars containing phthalic anhydride (78 wt %) and maleic anhydride (22 wt %)	Tar	Medium	1, V	12A, Calif. 12B, N.J. 12C, Texas
Still bottom from acetaldehyde production and by-product recovery operation	Liquids containing various aldehydes	Liquid	High	1, V	13A, Texas 13B, W.Va.

* Waste has high sodium content.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Steam still bottoms from aniline and alkylated phenol production	Mixture of phenolic compounds and aniline derivatives	Tar	Medium	2, IV	14, N.J.
Catch basin grease, nitrile pitch from production of surface active agents	Fatty alkyl acids, nitriles, and amines (C-8 to C-18 chain length), water (20%)	Solid	Medium	2, IV	15, Ill.
Solid residue from manufacture of aromatic amines	Long chain aromatic amines	Solid	Medium	2, IV	16, La.
Carbamate pesticides (Carbaryl)	Naphthol residues containing approximately 1% b-naphthol	Liquid	High	2, IV	17, W. Va.
Reactor tar bottoms from adiponitrile manufacture	Tars containing phosphoric acid (4.8 wt %) and adiponitrile	Tar	Medium	2, V	18, Texas
Acrylonitrile manufacturing wastes	Heavy ends containing acrylonitrile (CH_2 = CHCN), acetonitrile (CH_3CN), HCN and probably polymeric material	Tar	Medium	2, V	19A, Texas 19B, Texas
TDI manufacture reactor tar bottoms	Wastes in tar are cyclic biureates and a complex mixture of heavy organics; no analysis available. However, effluent gas from incinerator has the following composition: CO_2, 33.3%; H_2O, 26%; N_2, 38.8%; O_2, 5%; HCl, small amounts	Tar	Medium	2, V	20A, W. Va. 20B, La. 20C, La. 20D, W. Va.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Diphenylamine (DPA) manufacture reactor tar bottoms	Tars containing cyclic biureates (50%) and heavy organics (50%)	Tar	Medium	2, V	21A, N.J. 21B, La.
Waste from toluenediamine (TDA) production from dinitrotoluene (DNT)	Refining still residue containing TDA and other isomers of TDA	Thick Liquid	Medium	2, V	22A, N.J. 22B, W.Va.
Dinitrophenol wastes	Still bottom residue from dyestuff intermediates	Semi-solid	Medium	2, V	23, N.C.
DNT/MNT mix from DNT production	Sludge containing MNT (mononitrotoluene), DNT and possibly TNT and other organic solids	Sludge	Medium	2, V	24, W. Va.
Phenylamine tar wastes	Tars containing aniline (30%), nitrobenzene (5%), cyclic biureates (33%), and heavy organics (32%)	Tar	Medium	2, VI	25A, W.Va. 25B, N.J. 25C, La.
Wastes from polymer polyol production from polymerization of styrene with acrylonitrile	Liquid containing unreacted styrene and acrylonitrile	Liquid	High	2, VI	26, W. Va.
Vinyl chloride monomer manufacturing wastes	Dichloroethane and heavy chlorinated hydrocarbon wastes containing vinyl chloride	Liquid	Medium	3, I	27, Ky.
Organic chemical, capacitor, transformer production wastes containing PCB's and alpha methylstyrene	Waste containing PCB's and alpha methylstyrene, in capacitors	Solid	Low	3, II	28, N.Y.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Reactor bottoms from PVC manufacture	PVC resins containing 100 to 3000 PPM vinyl chloride monomer	Solid	High	3, III	29A, Texas 29B, N.J. 29C, Calif.
Epichlorohydrin manufacturing wastes	Heavy ends from fractionation column containing dichlorohydrin, epichlorohydrin, allyl chloride, and polymeric material	Tar	Medium	3, IV	30, Texas
Wastes from perchloroehtylene production	Still bottoms containing perchloroethylene, carbon tetrachloride, hydrocarbons, and other chlorinated hydrocarbons	Liquid	Medium	3, IV	31A, Texas 31B, La.
Hexachlorocyclopentadiene manufacturing wastes	Mixture of chlorinated toluenes, pentanes, and benzenes	Liquid	Medium	3, IV	32, N.Y.
Phenolic tar from 2,4-D manufacture	Typical composition: 2,4-dichlorophenol (8%), 2,6-dichlorophenol (2%), 2,4,6-trichlorophenol (35%), phenolic resins (55%)	Tar	Medium	3, V	33, Oregon
Organic pharmaceutical wastes	Liquid wastes containing mixture of organics such as phosgene, chlorobenzene, toluene, methanol methylene dichloride, tetrachloroethane	Liquid	Medium	3, VI	34A, N.J. 34B, Ind.
Chlorotoluene production wastes	Tars containing benzoyl chloride residues	Tar	Medium	3, VI	35, N.J.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Phenolic tar from MCPA manufacture	Typical composition: 4-MCPA (20%); 6-MCPA (20%), phenolic resins (60%)	Tar	Medium	3, VII	36, Oregon
Nitrochlorobenzene manufacturing wastes	Heavy ends and tars from orthochloronitrobenzene vacuum distillation	Tar	Medium	4, IV	37, Pa.
Amiben manufacturing wastes	Mixture of 90% water, 5% isomer, and 5% NaCl and Na_2SO_4	Liquid	Low	4, IV	38, N.J.
Dichloroaniline still bottoms	Mixture of isomers; containing 25% chlorine	Solid	Medium	4, VI	39, N.C.
Alkyl and aryl sulfonic acid manufacturing wastes	Emulsified oil and sulfones	Liquid	Medium	4, VI	40, Md.
Mercaptobenzothiazole (MBT) manufacturing wastes	Tarry mixture of 75% organic sulfur containing heterocyclics, 15% sulfur and 10% water	Tar	Medium	4, VII	41, N.J.
Dodecyl mercaptan manufacturing wastes	High viscosity liquid	Liquid	High	4, VII	42, N.Y.
Fluorinated herbicide wastes	Liquid containing aromatic fluorides	Liquid	Medium	4, VII	43, N.Y.
Halogenated aliphatic fumigants (ethylene bromide)	Mixture of brominated organic liquids containing 10-20% dibromopropanol from ethylene bromide manufactur	Liquid	Medium	4, V	44, Ark.
Urethane manufacturing wastes	Mixture of polyols and phosphate esters	Liquid	Low	4, VII	45, La.

Table 3-5. Hazardous Waste Properties and Sources (Continued)

Hazardous Waste Stream	Waste Stream Characteristics and Constituents	Physical Form	Heating Value	Waste Class and Priority Category	Potential Waste Sources and Locations
Organophosphorus pesticides (Malathion)	Off-specification technical grade malathion	Liquid	High	4, VI	46, N.J.
Tetraethyl orthosilicate wastes	Tetraethylorthosilicate liquid with traces of iodine, alcohol, "Genesolu" D	Liquid	Medium	4, VI	47, Pa.
Refinery spent caustic	Typical composition: Total Na^+ (1.45 wt %), total sulfur (2.58 wt %), water (81.0 wt%), other (11.97 wt %). Spent caustic solutions contain sulfides, mercaptides, sulfates, sulfonates, phenolates, naphthenates, and other similar organic and inorganic compounds	Liquid	Low	4, IV	Petroleum Refineries
Coke plant wastes	Weak ammonia liquor containing phenols, cyanides, chlorides, sulfates and total dissolved solid content of approximately 6000 mg/l	Liquid	Low	4, IV	49A, Calif. 49B, Pa.
Petroleum refining sour wastes	Waste contains sodium sulfides, H_2S, ammonium sulfide, phenol, mercaptans, acetic acid, cyanides, nitrogen bases	Liquid	Low	4, IV	Petroleum Refineries

the various thermal destruction technologies and equipment available. Results of the review indicated that the following processes and equipment types as selected by EPA were, indeed, the eight leading candidates to be considered:

- Liquid injection incineration
- Multiple hearth incineration
- Rotary kiln incineration
- Catalytic combustion
- Molten salt pyrolysis/combustion
- Pyrolysis
- Fluidized bed incineration
- Wet air oxidation.

The second step toward selection of facilities at which to conduct tests was the development of a procedure for rapidly determining which facilities would be most acceptable in meeting the following criteria:

- Potential for future in hazardous waste management
- Compatibility of waste form and expected incineration characteristics with incinerator capabilities
- Technical advantages and disadvantages of each type of incineration for a specific waste
- Adequacy of air pollution control equipment
- Availability of adequate sampling points
- Adequacy of instrumentation and monitoring of operating conditions
- Safety equipment and procedures
- Willingness of the facility management to be associated with this study.

The procedure chosen encompassed the following sequential steps:

1) Develop a list of thermal destruction facilities.
2) Develop procedures for screening the facilities to meet the above criteria.
3) Initiate telephone contacts to develop information on capabilities of facilities to meet criteria.

4) Visit selected facilities to make first hand observations on facility capabilities.

5) Evaluate facilities and establish a list of those recommended for testing.

The results of each phase of the procedures are described in the following sections.

3.2.1 Location of Thermal Destruction Facilities

Based on a survey of: (1) information provided by EPA, (2) information in TRW and ADL files, and (3) literature sources, a tentative listing of facilities for each of the eight classes of thermal destructors was prepared. Many of the facilities could not be categorized precisely as to the type of thermal destruction. However, it was generally possible to categorize each facility in the following manner:

a) Contractors, i.e., either engaged in the contract disposal of wastes or performing contract research and development work

b) Industrial users of thermal destruction processes

c) Manufacturers of thermal destruction equipment or sellers of processes.

In establishing the list of thermal destruction facilities, only those owned by or operated for the Armed Services were excluded. While the objective was to develop a list of commercial scale units or large scale pilot plants, at this stage it was not possible to ascertain the size or capabilities of the facilities. This was to be done during the telephone contact phase. The results of this phase established the following number of facilities for which telephone contacts would be made.

Rotary Kiln	13
Liquid Injection	23
Multiple Hearth	4
Fluidized Beds	12
Molten Salt	3
Wet Air Oxidation	4
Catalytic/Thermal	10
Pyrolysis	6

Although the above list was established, it was necessary to make arbitrary assignments of some facilities especially in the categories of Catalytic/Thermal and Pyrolysis. As an example, the B.F. Goodrich system is not a true catalytic unit. Rather, it is based upon the catalytic decomposition of the waste in a fluidized bed.

3.2.2 Facilities Screening Criteria

Before initiating telephone contacts of the list of facilities developed in Section 3.2.1, a number of evaluation criteria were established for which answers were required in order to determine if a visit to the facility was warranted or could be arranged. Foremost among these criteria was the facility management's interest in participating in this program and, if so, the equipment or methods for preventing the escape of off-gas pollutants from the thermal destruction process. Based on TRW/ADL experience with air pollution control systems, it was considered that a facility should be equipped with a wet scrubbing system since this type is the only one expected to have the potential capability of removing volatilized or partially degraded products should these occur in the off-gases. With the exception of wet air oxidation and pyrolysis - which are unique methods insofar as the volume and type of off-gases are concerned - if a facility did not have a wet scrubber system, the remaining information listed below was not usually obtained. If a facility was interested in participating and met the air cleaning criteria, information on the following items was requested:

- Process and equipment description
- Operating parameters
  - Feed rate or capacity
  - Operating temperature range
  - Physical limitations on feed
  - Residence times in reaction zone
  - Types of auxiliary fuel used
  - Materials of construction, especially off-gas system
- Waste handling, storage and pre-treatment capabilities
- Laboratory analytical facilities

- Sampling and instrumentation capabilities
- Previous experiences in hazardous waste destruction
- Type of arrangements to be made for tests
  - Charges
  - Schedules
  - Storage of wastes
  - Willingness to modify facilities for testing
- Safety provisions, liability insurances, and methods of residuals disposal
- Possibility of inspection visit to site of facility.

3.2.3 Results of Telephone Contacts

In Table 3-6 are recorded results of the telephone contacts for the two control criteria, i.e., the facilities interest in participation in the program and availability of pollution control equipment. This table also records the type of operator of each facility and records comments where appropriate. The general conclusions of the telephone contacts were:

1) Industrial owners of thermal destruction facilities did not, in general, want to participate in this program. Only three industrial sites (General Electric at Pittsfield, Mass., B.F. Goodrich at Calvert City, Ky., and the 3-M Company at Cottage Grove, Minn.,) indicated a willingness to participate during telephone contacts - and in most instances, subsequent letter contacts.

2) Contract destructors of wastes and contract research and development companies were generally eager to participate. Only Rollins Environmental Services of the major contract destructors declined to participate, on the basis that their present commitments to customers would not permit dedication of their facilities for the time required in this program.

3) The responses of the equipment manufacturers were mixed. Most manufacturers were unwilling to permit use of their pilot plant facilities in a program where there was obviously no immediate possibility of an equipment sale.

Table 3-6. Summary of Telephone Contacts

Facility Identification	Type of Operator*	Interested Yes	Interested No	Pollution Control Equipment Yes	Pollution Control Equipment No	Comments
Prenco	M	X		X		Visited
Rohm & Haas	U		X			
Eastman Kodak	U	X				Facility under construction
E.I. duPont de Nemounrs	U		X			
General Electric	U	X		X		Visited
Marquardt Co.	M	X		X		Visited
Pollution Abatement Services	C	X		X		Other liquid injection units judged more applicable
Seymour Mgf. Co.	C	X			X	
Chem-Trol Pollution Services, Inc.	C	X		X		Visited
Brule	M	X				No detailed information provided on facilities
Industrial Tank	C	X			X	

*M - Equipment manufacturer
U - Industrial user
C - Contract disposer or contract R&D

Table 3-6. Summary of Telephone Contacts (Continued)

Facility Identification	Type of Operator*	Interested		Pollution Control Equipment		Comments
		Yes	No	Yes	No	
B.F. Goodrich Chemical Co.	U	X				System part of process units only catalytic unit found.
Surface Combustion	M	X		X		Visited
John Zink	M	(Qualified)		X		
Dow Chemical	U		X			
Monsanto Co.	U		X			
Hyon Waste Management	C	X		X		Visited
Rollins Environmental Services	C		X			
Union Carbide	U		X			
Eimco/BSP	M	X		X		Visited
Nichols Engr. & Research	M	X		X		Visited
Pollution Controls, Inc.	C	X		X		Visited
3-M Company	U		X			Initially interested, visited
Petrolite Corp.	C	X			X	
Bio-Ecology Systems, Inc.	C	X			X	
Bartlett-Snow Products	M	X				Referred to Combustion Engineer

Table 3-6. Summary of Telephone Contacts (Continued)

Facility Identification	Type of Operator*	Interested Yes	Interested No	Pollution Control Equipment Yes	Pollution Control Equipment No	Comments
Fuller Company	M		X			
Georgia Pacific	U		X			
Oxy-Catalysts Inc.	M	X			X	Proposed 1-2 man year laboratory program for catalytic incineration of fumes
Air Pollutionomics	M	X				No available facilities
Trane-Thermal	M	X		X		Visited
Babcock & Wilcox	M	X		X		Visited
Eli Lilly	U		X			
Air Preheater	M		X			No answer to contact
Combustion Engineering	M		X			No answer to contact
Atomics Internationsl	M	X		X		Visited
Battelle Pacific Northwest Labs.	C	X			X	Laboratory scale molten salt unit
Anti-Pollution Systems	M	X			X	
Garrett Research & Dev.	M	X				Only lab equipment
Kemp Reduction Corp.	M		X			
Harbison-Walker	M					No answer to requests

Table 3-6. Summary of Telephone Contacts (Continued)

Facility Identification	Type of Operator*	Interested		Pollution Control Equipment		Comments
		Yes	No	Yes	No	
North American Mfg.	M	X				No answer to letter requests
Grand Equipment Co.	M	X				No answer to letter requests
Gardner-Denver	M					No applicable equipment
Allis-Chalmers	M		X			
MSI Industries	M					No facilities available
City of Baltimore	U					Unit not available for this program
Kennedy Van Saun	M		X			No answer to contacts
Wheelabrator	M	X				Unit under construction
Solvent Recovery Sources	C					Open pit incinerator
Procedyne	M	X				Laboratory and small pilot plant
Rhodia, Inc.	M					No applicable equipment
Nashville Thermal Transfer Corp.	U					No answer to contact
International Incinerator	M	X				Pilot plant in Denmark
General Motors	U		X			
Ford Motor Company	U		X			

Table 3-6. Summary of Telephone Contacts (Continued)

Facility Identification	Type of Operator*	Interested Yes	Interested No	Pollution Control Equipment Yes	Pollution Control Equipment No	Comments
Zurn Environmental	M					Facilities no longer available
Riley Stoker	M					No facilities available
Ingham County Grants Administration	U	X		X		Visited
Carborundum (Torrax)	M	X		X		Visited
Combustion Power Co., Inc.	M	X		X		Visited
Battelle Memorial Inst.	C	X		X		Visited
American Oil	U	X		X		Poor location and availability questionable
Dorr-Oliver	M					No facilities available
Chicago Bridge & Iron	M		X			
Copeland Systems	M					No facilities available
Infilco	M					No facilities available
Hazen Research	C	X		X		Visited
Hercules, Inc.	M		X			
Systems Tech.	C	X		X		Visited
Lockheed Bio Technology	M	X		X		Visited
Zimpro	M	X		X		Visited

Table 3-6. Summary of Telephone Contacts (Continued)

Facility Identification	Type of Operator*	Interested		Pollution Control Equipment		Comments
		Yes	No	Yes	No	
Barber-Colman	M	X		X		Visited
Liquid Waste Disposal	C	X			X	
Conservation Chemical Co.	C		X			
Northwestern Processing	C		X			
Resources Recovery Corp.	C		X			
Chemical Processors	C		X			
Sunbeam Equipment Co.	M					John Zink is subdivision.

3.2.4 Site Visits

Arrangements for site visits were generally made where there was both positive interest and pollution control equipment available. Preference was given to commercial scale units followed by large pilot plants. No laboratory scale facilities were considered. The largest number of facilities were found to be liquid injection incinerators as shown in Table 3-7 where the facility visits are listed. Although several other facilities listed in Table 3-6 which met the previous criteria were not visited, the reasons for not arranging a visit were as follows.

Table 3-7. Facilities Visited

Liquid Injection Incinerator

- Hyon Waste Management
- Marquardt
- Eimco/BSP
- Babcock & Wilcox
- Chem-Trol Pollution Serv., Inc.
- General Electric
- Prenco
- Trane-Thermal

Rotary Kiln

- 3-M Company
- Hyon Waste Management
- Pollution Controls, Inc.

Fluidized Beds

- Hazen Research
- Battelle Memorial Institute
- Systems Technology
- Combustion Power, Inc.

Pyrolysis

- Torrax (Carborundum)
- Ingham County Grants Administration
- Surface Combustion

Multiple Hearth

- Eimco/BSP
- Nichols Engineering & Research

Molten Salt

- Atomics International

Wet Air Oxidation

- Barber-Colman
- Zimpro
- Lockheed Bio Technology

Catalytic/Thermal

- No visits - B.F. Goodrich Chemical Co. only unit located

Recovery of Resources

- Chem-Trol Pollution Services, Inc.

Pollution Abatement Services:

Because of the large number of liquid injection facilities found which seemed more suitable for controlled testing, this site was not visited.

B.F. Goodrich Chemical Co.:

This site was not visited because permission to participate was received too late to make appropriate arrangements. However, since this is the only facility based on catalytic decomposition (in a fluidized bed) it was added to complete the table.

American Oil:

This fluidized bed facility located at the Mandan, S.D., refinery has been extensively evaluated under previous EPA contracts. Because its location is relatively far from the points of hazardous waste generation, and because of its use in an operating plant, no visit was made.

Although it is believed that other facilities might have suitable equipment available, there was often no response to follow-up contacts, or the responses as to interest were so qualified that it was judged that site visits would be unproductive.

During the site visits, amplification of the information sought during the telephone contacts was requested. Each of the site visits was conducted by at least one technically qualified individual. This individual was responsible for inspection of the facilities specifically to determine feasibility of conducting tests and to make an assessment of the general operability of the facility. This information was accumulated and evaluated for purposes of selecting the facilities for which tests would be recommended.

3.2.5 Selection of Facilities for Testing

A primary consideration for recommending a facility for testing was that it should be of commercial scale. However, after plant site visits, a number of other reasons resulted in reduction of those facilities given initial consideration. Those eliminated from final consideration and the reasons for their elimination are as follows:

3-M Company

Withdrew from consideration after the plant visit.

Torrax

Unit was decommissioned after plant visit.

Trane-Thermal

Pilot scale unit in poor operating condition.

Babcock & Wilcox

Pilot scale unit has limited capability compared with other liquid injection incinerators.

Eimco BSP

Liquid injection unit not comparable with other liquid injection facilities available.

Chem-Trol

Liquid injection incinerator was eliminated from consideration because of the low residence times and the difficulties that could be encountered in obtaining representative samples from the high temperature zone.

Nichols Engineering & Research Co.

Withdrew on the basis that wastes selected could not be adequately handled in pilot facility and because of reluctance to handle hazardous materials.

Hyon Waste Management

Liquid injection incinerator was eliminated from consideration because a large number of other liquid injection incinerators were found with greater potential for controlling conditions while using smaller volumes of wastes.

Battelle Memorial Institute

The pilot plant fluidized bed incinerator was judged to be less capable of achieving the flexibility of operation of a similar size unit located at Hazen Research, Inc.

Ingham County Grant Administration

This facility was eliminated because capital expenditures for equipment such as off-gas cleaning, storage, and handling would be required before tests could be made.

Lockheed Bio Technology

The laboratory nature of this installation when compared with the pilot plant capabilities of other wet air oxidation systems resulted in its elimination.

Combustion Power, Inc.

Unit not in operable condition, requires extensive refurbishment to perform tests.

The facilities recommended for Phase II testing along with the rationale for their selection are as follows.

LIQUID INJECTION INCINERATORS

Prenco

Two vertically fired units available with capacities of from 50 to 1500 gallons/hour. Turn down ratios (maximum rate/ minimum rate) of 8 to 10 are claimed. Have tested variety of industrial wastes.

Marquardt

Pilot plant unit is essentially full scale since multiple units are used in commercial installation. Capacity of 55 gallons/ hour is claimed. Have tested a number of industrial and hazardous wastes.

General Electric

This steam atomized unit has wide range of capabilities for varying residence times in high temperature zones - up to 12 seconds being possible. Nominal capacity is 20 million Btu/hr estimated to be from 200 to 400 gallons/hour. Burns a variety of company wastes on a routine basis.

ROTARY KILN INCINERATORS

Hyon Waste Management Services

This refractory lined rotary kiln is judged to be most typical of those used in industry. It has a design heat release rate of 55 million Btu/hr which is estimated to be from 550 to 1100 gallons/hr. Presently under contract to thermally destruct hazardous industrial wastes.

Pollution Controls, Inc.

This unlined, externally cooled rotary kiln is unique in its design. It has a capacity estimated to be from 500 to 1000 gallons/hr. Presently destructing hazardous wastes. New facility under construction in El Dorado, Arkansas, would provide additional test capabilities.

FLUIDIZED BED INCINERATORS

Systems Technology, Inc.

This large scale unit has an estimated capacity of 60 million Btu/hr. It is part of the Franklin, Ohio, municipal solid waste disposal system and has been extensively evaluated for its capabilities. Its selection was not only because of size but also because it would permit comparison of results with those obtained from incineration of solid wastes from municipalities. Have operated with a limited number of hazardous wastes.

Hazen Research

This pilot unit has a capacity of approximately 20 gallons/hr and was chosen because of: (1) its flexibility in controlling conditions, and (2) because some waste streams could not be obtained in the quantities necessary for test in a commercial scale unit. Have tested a variety of hazardous wastes.

WET AIR OXIDATION

Zimpro

The pilot scale unit was chosen because it is the basis for all commercial designs and the company has extensive laboratory capabilities for evaluating results. The capacity ranges are from 5 to 100 gallons/hr. The continuous, air agitated reactors represent the configurations most frequently installed in large scale facilities. Have tested a variety of hazardous wastes.

Barber-Colman

This pilot scale unit was chosen because it represents a new concept of sequential mechanically stirred reaction zones and because no commercial scale units are yet available. The capacity range is expected to be from 5 to 20 gallons/hr. Have tested a limited number of hazardous wastes.

MOLTEN SALT

Atomics International

Although classified as a pilot plant, this facility has the largest capacity of any molten salt facility available to date. Furthermore, has a good setup for obtaining samples, controlling conditions, and preventing pollution by off-gases. Have tested a limited number of hazardous wastes.

PYROLYSIS

Surface Combustion

Elimination of the other pyrolysis facilities as discussed previously left this facility as the only one for which tests could be scheduled. This facility is estimated to have a capacity of 2 million Btu/hr. Have limited experience with hazardous wastes.

MULTIPLE HEARTH INCINERATORS

Eimco BSP

It is expected that incineration of hazardous wastes with either sewage sludge or municipal refuse will be required for satisfactory operation. This pilot plant facility chosen because it has been used in the past in an EPA program and because of difficulties inherent in arranging for such tests in large scale multiple hearths operated by municipal governments. Its capacity is estimated to be in the range of 100 to 200 lbs/hr. Have tested a small number of hazardous wastes.

CATALYTIC/THERMAL

B.F. Goodrich Chemical Co.

Although this facility operates a proprietary process in a fluidized bed, it was chosen because of the catalytic nature of the unit for the destruction of organic liquids containing high concentrations of chlorine. These difficult-to-incinerate liquids are destroyed at a rate equivalent to 14 million Btu/hr. All other catalytic units were reported to require either gaseous feeds, which were not found among the wastes prioritized or liquids which could be completely vaporized - again not found among the waste sources.

RECOVERY OF RESOURCES

Chem-Trol Pollution Services, Inc.

> A proprietary process utilizing high chlorine content blended waste organic liquids in the manufacture of cement in Canada. It is claimed the energy content of the waste is utilized while simultaneously improving the quality of the cement. This process was chosen because it represents the recovery of resources from hazardous wastes. No U.S. installations are operable at the present time; however, it is anticipated that within 6 months one or more will be operating.

As a result of the surveys and consideration of the state of development of thermal destruction, the eight facility types were ranked into the following categories:

Category I - Widespread Applicability

- Liquid Injection Incinerators
- Rotary Kiln Incinerators
- Fluidized Bed Incinerators

Category II - Moderate Applicability

- Multiple Hearth Incineration
- Wet Air Oxidation
- Catalytic/Thermal
- Recovery of Resources (Chem-Trol cement manufacturing process)

Category III - Limited Applicability

- Pyrolysis
- Molten Salt

The bases for the above categorizations are as follows:

Category I. Three types of incinerators are currently in operation in industrial plants destroying hazardous wastes. As a result of their demonstrated performance they command first consideration. In addition, such units could be equipped with heat recovery wherever economically feasible.

Category II. Such restrictions as the need for auxiliary materials to accompany the solid wastes, the need for the feeds to be pumpable liquids or slurries or within a limited compositional range or the need for auxiliary treatment of effluents are expected to restrict the thermal destruction methods of Category II to specific applications.

Category III. Pyrolysis is expected to be limited to those wastes for which the pyrolyzed product, gas or char, do not contain toxic or hazardous substances such as chlorine, fluorine, nitrogeneous substance or heavy metals since there is too great a potential for their introduction into the environment. On the other hand, pyrolysis may also be considered as a recovery of resources process because of the byproduct gas and char generated.

Molten salt oxidation is expected to have a problem with disposal of residues; it must operate intermittently with possible frequent replacement of the molten salts and will probably have high operating costs. All of these reasons are expected to limit its applicability among the hazardous wastes considered in this work.

In summary, it is recommended that if the EPA must choose among the thermal destruction techniques to be demonstrated, this should be done on the basis of descending applicability as outlined above.

3.3 WASTE AND FACILITY MATCHING

Matching of the wastes and thermal destruction facilities was accomplished through the following procedures:

1) Each waste stream was evaluated to determine the suitability of destruction by each type of facility.

2) One applicable facility type was selected for each waste stream.

3) When more than one facility of that particular type was to be utilized, a specific facility was selected for a given waste.

The rationale, criteria, and results of the waste/facility matching are discussed in the following sections.

3.3.1 Rationale and Criteria

The overall objective of the waste/facility matching was to select the most applicable destruction facility for each waste stream. However, a specific requirement of this program is that at least one of each of the following types of destruction facilities be tested:

- Liquid injection incineration
- Multiple hearth incineration
- Rotary kiln incineration
- Catalytic combustion
- Molten salt pyrolysis/combustion
- Pyrolysis
- Fluidized bed incineration
- Wet oxidation.

The necessity to include each of these facility types influenced the waste/facility matching in a number of cases. For example, a waste that was equally applicable to either rotary kiln or wet oxidation destruction might be assigned to wet oxidation to insure a sufficient number of wastes for evaluating that type of facility.

The basic criteria for matching wastes to types of facilities were dependent on the following waste characteristics:

- Physical form: gas, liquid, slurry, sludge or solid
- Temperature range required for destruction: above 2000°F, 1400° to 2000°F, 700° to 1400°F, or below 700°F
- Off gases: primarily oxides of carbon, hydrogen, or nitrogen; but also halogen, sulfur, phosphorus, or volatile metal species
- Ash-nonfusible, fusible, and/or metallic
- Waste heating value: above 10,000 Btu/lb, 5,000 to 10,000 Btu/lb, or below 5,000 Btu/lb.

The characteristics of each waste stream were compared with the capabilities of each destruction facility type, using the waste/facility matching form presented in Figure 3-1. As illustrated by this sample maxtrix, the ability of each facility type to accommodate the physical form of the waste, reach the temperature range needed for suitable waste destruction, handle off-gases, and produce ash with suitable characteristics is tabulated. A tarry solid waste, for example, cannot normally be destructed in a liquid injection, multiple hearth, catalytic, fludized bed or wet air oxidation facility.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Tars from production of styrene

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2	3	(3)	2	1

ADDITIONAL CRITERIA AND REMARKS:

Pyrolysis is selected as the facility type for waste destruction because of the resource recovery (as fuel) potential and relatively low toxicity of the waste.

Figure 3-1. Waste/Facility Matching Matrix Sample

As indicated in the Figure 3-1 sample matrix, after the characteristics of the particular waste have been checked off against the facility type capabilities, the number of checks are added up and entered in the horizontal totals line. (Note that two or more temperature destruct ranges are counted as a single check mark in totaling the waste characteristics column.) For a specific waste and destruction facility type to be considered compatible, the total number of checks under that facility type must equal the number in the total line under waste characteristics.

By application of this procedure, three facility types (rotary kiln, molten salt and pyrolysis) were found to be suitable for destruction of the waste in the sample matrix (Figure 3-1). The additional criteria and remarks at the bottom of the matrix form indicate that of the three possible facility types, pyrolysis may be a good candidate because of potential energy recovery with this waste due to its high heating value. The estimated heating value in Btu/hr (near upper left corner, Figure 3-1) is utilized in assessing the probable need for supplementary fuel - an additional consideration in selecting a destruction facility.

A waste/facility matching matrix was completed for each of 97 waste streams evaluated. The consensus work sheets for the 50 selected wastes are included in Appendix A. From the matrix, one or more possible destruction facility types were selected. The data from the 50 matching matrix forms are listed in Table 3-8. Next, a particular facility type was selected for each waste, based on criteria such as pollution control and safety considerations, previous destruction experience by a specific facility, and potential for resource recovery (usually by pyrolysis). As previously discussed, the requirement of utilizing each of eight different types of destruction facilities also influenced the waste/facility matching. Table 3-8 indicates the choice of a facility type for each waste.

The final step in the matching procedure was the assignment of each waste to a specific destruction facility when more than one facility of that type was selected for testing. Criteria for choosing between more than one facility of the same type included: existence of pollution control devices· need for safety evaluations; previous experience of each

Table 3-8. Waste/Facility Matching Tabulation

Hazardous Waste Stream	Physical Form	Heating Value	Waste Class and Priority Category	Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation	Comments
1 Ethylene glycol manufacturing wastes	Liquid	Low	I, II	ⓧ		x	x	x		x		Large volume liquid waste - G.E. liquid incinerator selected
2 Off-specification isoprene	Liquid	High	I, III	ⓧ		x	x	x		x		Unstable liquid - Marquardt liquid incinerator selected
3 Off-specification phenol	Liquid	High	I, III	x		x	x	x		ⓧ	x	Large volume liquid - Systems Tech claims access to large quantities locally
4 Evaporator residue from the cumene process for phenol manufacture	Tar	Medium	I, IV			ⓧ		x	x			Hazardous tarry waste - rotary kiln selected. Source is nearer Dow than [illegible]
5 API separator bottoms	Sludge	Medium	I, IV		x	x		x	ⓧ	x		Potential resource recovery as fuel, relatively low toxicity - pyrolysis selected
6 Waste residues from alkyl benzene production	Liquid	High	I, IV	ⓧ		x	x	x		x		Large volume liquid waste - G.E. liquid incinerator selected
7 Tars from production of styrene	Tar	Medium	I, IV			x		x	ⓧ			Potential resource recovery as fuel, relatively low toxicity - pyrolysis [illegible]
8 Rubber manufacturing waste sludge	Solid	Medium	I, IV		x			x	ⓧ	x		Potential resource recovery as fuel, relatively low toxicity, regarded as difficult to incinerate - pyrolysis selected
9 Isophthalic acid and terephthalic acid still bottoms	Solid	Medium	I, V		ⓧ	x		x	x	x		One of the few waste streams suitable for destruction in multiple hearth
10 Ethylene manufacturing wastes	Liquid	High	I, V	x		x	x	x		ⓧ		Large volume waste suitable for fluidized bed destruction - Systems Tech selected
11 Organic peroxide manufacturing wastes (from dicumyl peroxide manufacture)	Liquid	High	I, V	x		x	x	x		ⓧ		Waste has high sodium content, more suitable for fluidized bed than liquid incinerator - [illegible] selected
12 Tars from production of phthalic anhydride (xylene process)	Tar	Medium	I, V			x		x	ⓧ			Potential resource recovery as fuel, relatively low toxicity - pyrolysis selected
13 Still bottom from acetaldehyde production and by-product recovery operation	Liquid	High	I, V	ⓧ		x	x	x		x		Large volume liquid waste; source is nearer to [illegible] than G.E.
14 Steam still bottoms from aniline and alkylated phenol production	Tar	Medium	I, IV			ⓧ		x	x			Large volume tarry waste - rotary kiln selected (pollution controls)
15 Catch basin grease, nitrile pitch from production of surface active agents	Solid	Medium	I, IV			ⓧ		x	x			Large volume tarry waste - rotary kiln selected, source near [illegible]

x Possible facility types for destruction of each waste

ⓧ Selected facility type for each waste

Table 3-8. Waste/Facility Matching Tabulation (Continued)

Hazardous Waste Stream	Physical Form	Heating Value	Waste Class and Priority Category	Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation	Comments
16 Solid residue from manufacture of aromatic amines	Solid	Medium	2, IV		ⓧ	x		x	x	x		One of the few waste streams suitable for destruction by multiple hearth
17 Carbamate pesticides (Carbaryl)	Liquid	High	2, IV	x		x	x	x		ⓧ		Large volume waste suitable for fluidized bed destruction - Systems Tech selected
18 Reactor tar bottoms from adiponitrile manufacture	Tar	Medium	2, V			ⓧ		x	x			High volume tarry waste - rotary kiln selected (Pollution Controls)
19 Acrylonitrile manufacturing wastes	Tar	Medium	2, V			ⓧ		x	x			Tarry waste - rotary kiln selected (Pollution Controls)
20 TDI manufacture reactor tar bottoms	Tar	Medium	2, V			ⓧ		x	x			Tarry waste - rotary kiln selected (Hyon)
21 Diphenylamine (DPA) manufacture reactor tar bottoms	Tar	Medium	2, V			ⓧ		x	x			Tarry waste-rotary kiln selected (Hyon)
22 Waste from toluenediamine (TDA) production from dinitrotoluene (DNT)	Thick Liquid	Medium	2, V			x		x		ⓧ		Large volume waste suitable for fluidized bed destruction - Systems Tech selected
23 Dinitrophenol wastes	Semi-solid	Medium	2, V			x		x			ⓧ	Similar types of waste successfully destroyed by wet air oxidation - Resource Recovery selected
24 DNT/MNT mix from DNT production	Sludge	Medium	2, V		x	x		ⓧ	x	x		Waste sludge may contain TNT and potentially explosive - molten salt selected
25 Phenylamine tar wastes	Tar	Medium	2, VI			ⓧ		x	x			Tarry waste - rotary kiln selected (Pollution Controls)
26 Wastes from polymer polyol production from polymerization of styrene with acrylonitrile	Liquid	High	3, VI	ⓧ		x	x	x		x		Low volume liquid waste - Marquardt selected
27 Vinyl chloride monomer manufacturing wastes	Liquid	Medium	3, I	x		x	ⓧ	x		x		B.F. Goodrich Chemical Co. generates this waste and operates catalytic fluidized bed (Catoxid) reactor
28 Capacitor wastes containing PCB's	Solid	Low	3, I			ⓧ		x		x		Waste is mixture of large solids and liquid-rotary kiln selected (Hyon)
29 Reactor bottoms from PVC manufacture	Solid	High	3, III		ⓧ	x		x		x		One of the few waste streams suitable for destruction by multiple hearth
30 Epichlorohydrin manufacturing wastes	Tar	Medium	3, IV			ⓧ		x				Tarry waste - rotary kiln selected (Pollution Controls)
31 Wastes from perchloroethylene production	Liquid	Medium	3, IV	ⓧ		x		x		x		Large volume liquid waste - G.E. selected

x Possible facility types for destruction of each waste

ⓧ Selected facility type for each waste

Table 3-8. Waste/Facility Matching Tabulation (Continued)

Hazardous Waste Stream	Physical Form	Heating Value	Waste Class and Priority Category	Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation	Comments
32 Hexachlorocyclopentadiene manufacturing wastes	Liquid	Medium	3, IV	ⓧ		x	x	x		x		Similar liquid waste assigned to GE — selected Marquardt for this waste
33 Phenolic tar from 2,4-D manufacture	Tar	Medium	3, V			ⓧ		x				Tarry waste — rotary kiln selected, source nearer Pollution Controls
34 Organic pharmaceutical wastes	Liquid	Medium	3, VI			x		x		ⓧ		Low volume liquid waste — Hazen fluidized bed selected
35 Chlorotoluene production wastes	Tar	Medium	3, VI			ⓧ		x				Tarry waste — rotary kiln selected (Pollution Controls)
36 Phenolic tar from MCPA manufacture	Tar	Medium	3, VII			x		ⓧ				Similar waste assigned to rotary kiln — select molten salt for this waste
37 Nitrochlorobenzene manufacturing wastes	Tar	Medium	4, IV			ⓧ		x				Tarry waste — rotary kiln selected (Huber)
38 Amiben manufacturing wastes	Liquid	Low	4, IV	x		x	x	x		ⓧ		Large volume waste — high water and sodium salt content — Systems Tech fluidized bed selected
39 Dichloroaniline still bottoms	Solid	Medium	4, VI		x	x		ⓧ		x		Waste difficult to incinerate — molten salt selected
40 Alkyl and aryl sulfonic acid manufacturing wastes	Liquid	Medium	4, VI	ⓧ		x		x		x		Liquid waste — Trane selected
41 Mercaptobenzothiazole (MBT) manufacturing wastes	Tar	Medium	4, VII			ⓧ		x				Tarry waste — rotary kiln selected (Huber)
42 Undecyl mercaptan manufacturing wastes	Liquid	High	4, VII	ⓧ		x		x		x		Low volume liquid waste — Marquardt selected
43 Fluorinated herbicide wastes	Liquid	Medium	4, VII	ⓧ		x		x		x		Only fluorine containing waste (not compatible with most facilities) — Marquardt selected
44 Halogenated aliphatic fumigants (ethylene bromide)	Liquid	Medium	4, V	x		x	x	x		ⓧ		Only bromine containing waste — Hazen fluid bed selected
45 Urethane manufacturing wastes	Light	Low	4, VII	x		x		x		ⓧ		Waste is mixture of polyols and phosphate esters — Hazen fluidized bed selected
46 Organophosphorus pesticides (malathion)	Liquid	High	4, VI	ⓧ		x		x		x		Liquid waste containing both phosphorus and sulfur — Marquardt selected
47 Tetraethyl orthosilicate wastes	Liquid	Medium	4, VI	x		x	x	x		ⓧ		Low volume waste containing silicon — Hazen fluidized bed selected
48 Refinery spent caustic	Liquid	Low	4, IV	x		x	x	x		x	ⓧ	One of the few wastes suitable for destruction by wet air oxidation. Resource Recovery has successfully destructed this waste

x Possible facility types for destruction of each waste

ⓧ Selected facility type for each waste

Table 3-8. Waste/Facility Matching Tabulation (Continued)

Hazardous Waste Stream	Physical Form	Heating Value	Waste Class and Priority Category	Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation	Comments
49 Coke plant wastes	Liquid	Low	4, IX	x		x	x	x		x	ⓧ	One of the few wastes suitable for destruction by wet air oxidation. Zimpro has extensive experience with this waste and 3 plants under construction
50 Petroleum refining sour wastes	Liquid	Low	4, IX	x		x	x	x		x	ⓧ	One of the few wastes suitable for destruction by wet air oxidation. Zimpro has extensive experience with this waste and has plant under construction

x - Possible facility types for destruction of each waste

ⓧ - Selected facility type for each waste facility with similar wastes; logistics considerations such as quantity of waste available for large commercial or industrial destructors; and geographic proximity of the waste source to the destruction facility. The rationale for selection of specific facilities of each type is indicated in the "comments" column of Table 3-8.

3.3.2 Waste/Facility Matching

The final matching of wastes and facilities is summarized in Table 3-9. The previously described rationale and criteria for matching were applied to each of the 50 selected wastes, which were then assigned to 13 different facilities. One waste in addition to the 50 selected will be a proprietary blend of highly chlorinated wastes routinely destructed as a supplementary fuel in a rotary cement kiln. This proprietary waste fuel is blended at Chem-Trol Pollution Services, Inc., the fourteenth facility selected for this program. The Chem-Trol fuel is used to recover thermal energy and chlorine from the waste blend utilized in the cement production process.

The assignment of the 50 selected wastes (plus the Chem-Trol waste blend) to 14 facilities of 8 different types is as follows:

Liquid Injection	(3)	Marquardt	- 6 wastes
		General Electric	- 3 wastes
		Prenco	- 2 wastes
Multiple Hearth	(1)	Eimco BSP	- 3 wastes
Rotary Kiln	(3)	Pollution Controls	- 7 wastes
		Hyon Waste Management	- 7 wastes
		Chem-Trol	- 1 waste
Catalytic	(1)	B.F. Goodrich	- 1 waste
Molten Salt	(1)	Atomics International	- 3 wastes
Pyrolysis	(1)	Surface Combustion	- 4 wastes
Fluidized Bed	(2)	Systems Technology	- 5 wastes
		Hazen Research	- 5 wastes
Wet Air Oxidation	(2)	Zimpro, Inc.	- 2 wastes
		Resource Recovery	- 2 wastes
Total Facilities	14	Total Wastes	51 (including Chem-Trol blend)

Table 3-9. Waste/Facility Matching Summary

Liquid Injection	Multiple Hearth	Rotary Kiln	Catalytic	Molten Salt	Pyrolysis	Fluidized Bed	Wet Air Oxidation
Marquardt Co.	[illegible]	[illegible]	B.F. Goodrich	Atomics International	Surface Combustion	Systems Technology	Zimpro, Inc.
Off-spec isoprene Hexachlorocyclopentadiene still bottoms Organophosphate pesticides (malathion) Waste from polymer polyol production (polymerization of styrene with acrylonitrile) Dodecyl mercaptan wastes Fluorinated herbicide waste	Reaction bottoms from [illegible] manufacture Aromatic amine residues Isophthalic acid and terephthalic acid still bottoms	[illegible] manufacturing wastes Steam still bottoms from aniline and alkylated phenol production Acrylonitrile manufacturing wastes Reaction tar bottoms from acrylonitrile manufacture Phenolic tar from 2,4-D manufacture Chlorotoluene production wastes Phenylamine tar wastes	Vinyl chloride monomer manufacturing wastes: dichloroethane and heavy chlorinated hydrocarbon wastes that contain vinyl chloride	DNT-MNT mix waste from DNT production Dichloroaniline still bottoms Phenolic tar from MCPA manufacture	API separator bottoms Tars from production of styrene Rubber manufacturing waste sludge Tars from production of phthalic anhydride (xylene process)	Off-spec phenol Amiben manufacture liquid wastes Carbaryl manufacture wastes Ethylene manufacturing wastes Wastes from toluene diamine (TDA) production from dinitrotoluene (DNT)	Coke plant wastes Petroleum refining sour wastes
General Electric Co.		Hyon Waste Management				Hazen Research	Resource Recovery
Ethylene glycol manufacture residue Waste residues from alkyl benzene production Perchloroethylene manufacture still bottoms		PCB (polychlorinated biphenyls) wastes in capacitors Evaporate residue from the cumene process for phenol manufacture Nitrochlorobenzene tars Cation based grease, [illegible] still from production of surface active agent TDI manufacture reaction tar bottoms Diphenylamine (DPA) manufacture reaction tar bottoms Mercaptobenzothiazole (MBT) tars				Tetraethyl orthosilicate wastes Organic wastes from pharmaceutical manufacture Organic peroxide manufacturing wastes (from dicumyl peroxide manufacture) Ethylene bromide manufacturing wastes Urethane manufacture wastes	Refinery spent caustic Dinitrophenol wastes from dye manufacture
Prenco Manufacturing		[illegible] Pollution Services					
Still bottoms from [illegible] production and by-product recovery operation Alkyl and aryl sulfonic acid wastes		[illegible] proprietary blended waste (high chloride organics)					

3.4 PREPARATION OF DETAILED PHASE II PLAN

Preparation for the Phase II testing effort is key to the successful implementation of this work. The overall rationale and basic operating assumptions used in developing the detailed Phase II plans are discussed in this section. Most of the specific details are discussed in Volume II, Phase II Test Plans. Certain elements which are common to the entire test program, such as sampling and analysis, are given in detail in this section. Particular sampling requirements unique to a facility are identified in the discussion of that facility contained in Volume II of this report.

3.4.1 Test Program

Objectives

Development of the experimental test series was based upon obtaining information which will contribute to the overall program as well as insure that the tests are conducted in an environmentally acceptable manner. The Phase II test program plans described in this section and detailed by thermal destruction facility in Volume II, were developed with the following objectives in mind.

- Determine the effectiveness of commercial scale facilities for thermal destruction of hazardous wastes.
- Obtain experimental data in such a manner that the results can be utilized to develop guidelines or regulations for the disposal of hazardous wastes in an environmentally acceptable manner.
- Assure that no unexpected emissions of hazardous species occur during the conduct of the tests.
- Obtain data which will indicate the probable optimum conditions for destruction of a waste in a particular facility.
- Assure that the tests are conducted in a safe manner and within the operating limits of the equipment.

Approach

Most of the tests will be conducted in facilities which may be generically described as incinerators. Wet air oxidation and pyrolysis units are each unique as types and significantly different from conventional incinerators from the point of view of sampling and analysis requirements. The analytical objectives of the tests will be to measure emissions of the hazardous waste species, their primary decomposition products (such as HCl), secondary reaction products (pyrolysis and partial oxidation species) and any other species which may be generated and could be of concern.

Consideration of the typical conditions encountered during field testing indicates that only one test condition can be adequately sampled in duplicate during the sampling crew's operating day. Facility operating costs and waste quantities required for long duration runs make it economically impractical to achieve completely steady-state sample concentrations in any component of a facility, especially in the case of quench/scrubber solutions. For that reason the samples which are to yield the most useful data on incinerator effectiveness will be taken in the hot zone at the exit of the reaction chamber and before any quench or scrubber sections. Gas samples will also be collected after the scrubber in order to give some indication of scrubber effectiveness and to ensure that emission standards have not been exceeded. Where applicable, samples will be collected from the ash or slag and scrubber liquor to complete the total emissions data. Samples will be collected from the scrubber solutions and the stack gases: (1) as a possible check on the hot zone sample, (2) especially to be sure no critical species have been emitted to the environment, and (3) to provide preliminary guideline data on the distribution of emission species in the control systems. In this manner samples may be collected for analysis which represent the entire effluent from the facility.

Due to the time duration desired for the completion of the program and the number of facilities and wastes to be studied, an approach has been developed using two equivalent experimental teams. Each team will consist of a field and laboratory component. The basic composition of each field team represents a four person effort including one chemical engineer, two samplers and one chemist/instrumentation specialist. The laboratory staff will also represent approximately a four person effort. Those people will have a full spectrum of analytical capabilities including mass spectrometry, chromatography, colorimetric and other instrumental analyses.

To facilitate the field program, two trailers will be equipped as mobile laboratories. These will contain the process instrumentation, sample preparation area, and equipment storage space. The process analyzers will be used primarily to establish each test burn operating condition. One trailer will be outfitted in each of the two contractor laboratories and then transferred to each of the test facility locations.

Test Plan

The sequence of an individual waste test at a facility will include the following general elements, all properly scheduled to accommodate any particular modifications which may need to be made:

1) Schedule facility and waste
2) Secure waste
3) Arrange for a presite visit for preparation of site and equipment for sampling and analysis, and waste storage and handling
4) Transport waste to site and arrange storage
5) Prepare the site (the facility staff will arrange this in most cases)
6) Pre-treat or condition wastes as required
7) Conduct tests
    Establish conditions
    Collect samples
8) Cleanup and relocate test crew and instrumentation trailer.

Test Sequence

The basic protocol to be used during each waste test condition may be represented by the following elapsed time/crew activity schedule (Table 3-10) which shows the interrelated activities of the facility operating crew and the TRW or ADL sampling crew.

Table 3-10. Typical Crew Activity Schedule

Elapsed Hours	Facility	Sampling Crews
Variable	Startup or maintained condition	Equipment preparation, calibration, etc.
1	Stabilized conditions, auxiliary fuel only	Collect background samples and waste feed samples
1-2	Charge waste and stabilize operating conditions	Initiate on-line instrumentation and monitor operating characteristics
1	Maintain Operating Conditions	Collect first set of samples
1		Change over sampling equipment
1		Collect second set of samples
Variable	Standby or shutdown mode	Change over sampling equipment and prepare for next test conditions

The background samples will be collected during the most convenient time prior to charging the test waste. Dependent on the facility routine for recharging scrubbers, etc., and overall schedule, this may be on the day preceding the test burn or after the facility is brought to appropriate thermal conditions before charging waste.

3.4.2 Logistical Considerations

Logistical support for Phase II involves: (1) the timely placement of sampling crews and instrumentation at each thermal destruction facility; (2) acquisition, transportation, storage and disposition of test quantities of wastes; and (3) the handling and disposition of all samples. In addition, preparatory work must include coordination and confirmation that appropriate facility modifications (installation of sampling ports, utilities, scaffolds, etc.) have been implemented so as not to delay the actual test effort. This section describes the overall logistical plan. Specific details or exceptions related to a given facility are presented in Volume II for that particular facility.

Sampling Crews

Sampling crews will utilize ground and/or air transportation to the facility test site, arriving from 1 to 4 days in advance of the scheduled test burns. The transportation mode will depend upon the test site location relative to either TRW or ADL. The number of days allocated to the sampling crew for setup, interfacing, and checkout of all instrumentation and sampling apparatus varies depending upon the size and complexity of the facility. In addition, more pretest time is allocated for the first few facilities to permit shakedown of procedures and instrumentation. The mobile equipment trailer containing on-line and grab sampling instrumentation, recorders, sample preparation facilities, auxiliary process instrumentation, etc., will be transported to the test sites. Transport of these trailers from one facility to the next will be accomplished by commercial cartage companies. Delivery of the trailers will be timed such that they will be on-site and spotted in position before the arrival of the sampling crew.

Wastes

Wastes will be acquired from the sources and shipped via truck to the facilities. In most instances, the wastes will be shipped in 55-gallon drums. For large capacity facilities – for example Hyon Pollution Controls, Inc., and Systems Technology - tank trucks may be employed. Waste loading into drums or tank trucks will be accomplished by personnel of the company from which the wastes are acquired. For some tarry materials, heated tank trucks may be advantageous to avoid setup of the waste. This determination will be made as a result of the final negotiations with the facility operators and a more precise understanding of the given wastes. Commercial trucking firms will be utilized for waste transportation. Prior analysis of the wastes to be acquired will establish their proper identification and marking for shipment. Transporters of these wastes will be required to meet all necessary local, state, and federal regulations governing shipment of these materials.

Delivery of wastes will be scheduled into the facilities with sufficient lead time to permit facility personnel to perform routine waste characterization tests, bench-scale thermal destruction tests (where necessary), and waste pretreatment as required. It is anticipated that waste delivery to the facility will occur 3 to 4 weeks in advance of the scheduled test burns. Appropriate storage facilities will be established for each waste. Provisions will be made to examine the stored wastes periodically in order to prevent unsafe conditions. In some instances, heated storage facilities may be required to minimize solidification of tarry wastes.

Facility

Arrangements will be made for the location of the equipment trailer during the period of the test program at each facility. Utilities such as power for the trailer and sampling equipment, and water for the hot gas sampling probes will be located or established as necessary. All personnel and detailed mechanical interfaces will be defined as a result of the pre-test site visit.

3.4.3 Health and Safety Aspects

The protection of the health and safety of all personnel involved in this program is of paramount importance in preparation for the tests, during the tests and in subsequent disposal or treatment of residues. The degree of hazardousness associated with these chemical wastes varies widely from that which affects people immediately, through reactions such as burns and respiratory effects, to long term effects such as cancer. It is especially important in this program to insure that safe handling procedures be observed because of the experimental nature of the tests; i.e., for many of the wastes this may be the first time that large scale thermal destruction has been attempted. Consideration of the sequential steps involved in this program indicates that plans for health and safety programs must be developed for the following operations:

1) Collection and preparation of wastes for shipment

2) Transportation of wastes

3) Receipt and storage of wastes at site of thermal destruction facility

4) Test period

5) Clean-up of facilities and disposal of residuals.

Because these steps are reasonably discrete, the health and safety programs w. l be specifically addressed with reference to the personnel involved in each stage.

Waste Preparation and Shipment

Preparation of the wastes for shipment is expected to be carried out by personnel at the generation site. Since the waste sources are typically large chemical companies with established procedures for protection of the health and safety of its employees, it is not planned to develop any special instructions for protection and storage. It is important to assure that any additives introduced for purposes of waste stabilization will not adversely affect the test burn. Neutralization with caustic for example, would introduce sodium into the waste stream which could cause deterioration of the combustion chamber walls.

Waste Transportation

Transportation of the wastes from the source to the site of the thermal destruction facilities will be by licensed carrier, and all conditions prescribed for the transport of hazardous wastes by the U.S. Department of Transportation and the Interstate Commerce Commission will be observed.

Facility Waste Handling

Although some of the facilities routinely process a large number of chemical wastes of various hazard levels, the consensus of the plant inspection teams was that procedures for safety handling hazardous wastes at most of the facilities have not been formalized, and that there is no routine safety program. Nevertheless, these companies are generally familiar with the procedures for examining and approving receipt of wastes from the point of view of leaking containers, valves, etc. Each facility operator will be informed of the hazardous characteristics of the waste insofar as they are known. It is expected that this will take the form of identifying the source and type of wastes along with a description of the controlling hazardous rating, e.g., - oral toxicity, dermatitis, carcinogenic, etc.

Testing

The most critical period for possible exposure to hazardous conditions will be during the test periods because the chemical wastes must be prepared and fed into the thermal destructor. Not only will a much larger number of personnel be involved but there will be two crews, i.e., the plant operating crew and the sampling crew. Therefore, safety procedures will be established at each location, including:

- Briefing the contractor's test crew by the TRW or ADL program director on the safety requirements for handling each waste. Each test will have a crew chief who will have the responsibility of insuring that the crew operates in a safe manner with special attention to the safety requirements of the facility operator.
- Briefing the operator's personnel, by the test contractor's (ADL or TRW) crew chief will be performed. The hazardous nature of each individual waste will be described and special precautions for handling will be described. In particular this will include the need for special protective clothing, respirators, and operating procedures; and the necessity for adhering to the specified conditions, but not at the expense of health and safety.
- Establishing operating parameters such as temperature and feed rates that can be safely handled in the equipment. This will be the responsibility of the facility operator.
- Reviewing emergency procedures for accident conditions in conjunction with the facility operator. Crews will be briefed in established procedures.

Site Cleanup

The clean-up of the facilities, disposal of residues, and disposition of shipping containers are expected to present potential health and safety problems. In most instances, the same handling precautions will prevail during clean-up of facilities as was necessary during the tests. However, there may be some facilities where outside firms are retained to clean up facilities; in those instances the contractor crew chief will review the necessary safety precautions with the clean-up firm personnel. The disposal of any residues, e.g., ash or other solids discharged or removed from the equipment, will be carried out only after analysis and then only by approved landfill methods if further destruction cannot be achieved. The most difficult disposal problem is expected to be the drums used to ship tarry or solid substances. The present disposal methods used by the facilities, e.g., washing followed by crushing and landfill disposal, will be evaluated, and special provisions will be made if these methods are unacceptable for the particular waste containers.

3.4.4 Environmental Considerations

The primary reason for examining thermal destruction as a method of toxic and hazardous waste disposal is to minimize negative environmental impacts associated with alternative disposal methods. It is recognized, however, that undesirable environmental problems could result during the implementation of the Phase II test program. These are considered in the following paragraphs together with actions that will be taken to prevent such negative occurrences.

Because considerable quantities of hazardous wastes must be transported over relatively long distances, the possibility exists for accidents occurring which might result in widespread dispersion of the wastes. The degree of dispersion from such accidents is greatest, of course, for liquids or slurries, which are expected to comprise slightly over one-half of the wastes. The most effective methods for minimizing their potential dispersion is to take steps to prevent accidents from occurring and to provide contingency plans for coping with any accidents. Therefore, collection and transportation of these wastes shall be performed only by licensed transportation companies operating under the rules and regulations of the Department of Transportation. In addition, the shipping route will be supplied to both the company furnishing the wastes and to the Contractor's personnel, along with the names and telephone numbers of designated personnel to whom any accidents should be reported. Appropriate cognizance of these shipments will be obtained from the chemical industry's program that provides for emergency directions in case of accidents during transportation.

At the site of the tests there are a number of possible conditions which might cause adverse environmental impact. Foremost among these are the possibility that incomplete destruction of the wastes might result in the emission of hazardous substances. Because the most difficult situation to cope with is airborne pollutants, every facility chosen for testing has air pollution control equipment usually in the form of water scrubbers operating with recycle of the scrubber liquid. Furthermore, the test program will include continuous monitoring of the off-gases for carbon monoxide and hydrocarbons as an indication of the completeness of combustion. Should this instrumentation indicate concentration levels above preestablished maximums, the test will be aborted. Since these control analyses can be made rapidly, it is not anticipated that the quantities emitted will have a significant environmental impact, especially since rapid large dilutions will occur and the total amount emitted will be small before ordering cessation of the tests.

Disposal of water from the scrubber systems may become a problem should these waters become highly polluted. In some systems, such as wet air oxidation, biological treatment may be capable of removing pollutants from scrubber water, especially when combined with other wastewaters in municipal sewage treatment plants. In other systems, the small amounts of effluents from highly recycled scrubber systems may be further concentrated by evaporation, and residues again sent through the incinerator. Because it is impossible to predict the success of thermal destruction of a waste in advance, the most severe conditions, i.e., those believed to have the greatest potential for destruction, will be performed initially. Evaluation of initial test results will be utilized to determine if less severe conditions, i.e., lower temperatures, should be included in the tests. However, each test situation and test site must be considered as unique, and an analysis shall be performed of the potential environmental impact of the air and water emissions in order to insure that maximum environmental protection is achieved.

Residuals, such as empty containers and ashes, will present a solid waste disposal problem. In some facilities, e.g., rotary kilns, it will be possible to send shipping containers through the incinerator; in other facilities it will be necessary to effect other disposal methods. Each situation will be examined individually to insure that those residuals have: (1) the minimum possible amounts of pollutants, and (2) are disposed of in the most environmentally acceptable manner. Disposal of these residuals will be into approved landfills. Because of the anticipated small volumes compared with the original volumes, the net effect will be a reduction in the potential environmental impact.

Finally, no tests will proceed before assurance has been established that the facilities are operating within their limits as established by permits by cognizant regulatory bodies. For example, we have found some facilities where regulatory permits establish minimum operating temperatures and, therefore, no tests can be carried out below those conditions. Besides insuring that the test facilities are operated within appropriate regulatory limits, a simplified environmental impact analysis shall be performed. It is anticipated that this analysis will rely upon development of a check-list of items to be investigated for environmental effects, and evaluating each of these prior to initiation of the test programs. Site visits during Phase I indicated that there should be no problems encountered because each site has been processing wastes of various degrees of hazardousness; however, only through continual vigilance will it be possible to insure minimal environmental impact.

3.4.5 Process Instrumentation

Instrumentation of various degrees of sophistication will be required to monitor facility operational parameters; measure fuel, waste, water and air feed rates; and monitor the gas composition of the incinerator effluent. While some of the facilities have adequate process instrumentation for monitoring operating conditions, in general it may be necessary to add or modify appropriate equipment to acquire the basic operating data. This section briefly describes the types of equipment or instruments that will be used for each of the measurements.

Process Type Measurements

Measurements required in this category are those of input waste, auxiliary fuel, air, and the scrubber water (solution) feed rates. Incinerator (or reaction chamber) temperature and pressure should also be known.

Waste feed rates will be measured by a variety of techniques chosen, based on the physical characteristics of the waste and the feed mechanics of the facility. Liquid or solution feed rates may be measured with in-line flow meters, or direct volume or weight measurements on an intermittent basis. In the case of tarry wastes and solids it may be necessary to estimate the average feed rate by weighing a representative number of drums (or other units) and tabulating the rate of charging during the duration of the test period.

In cases where auxiliary fuel is used, oil feed rates can be measured with an in-line orifice meter, and gas feed rates would normally be read from the dry gas meter. In most facility/waste combinations it is anticipated that input air rates will be calculated from stack gas composition and velocity. This approach assumes that total feed composition and combustion efficiency are constant; however, normal variations should not significantly affect the calculated values. In general, air flow will be determined using standard pitot techniques.

Water or caustic solution feed rates to quench and scrubber sections will be measured using either in-line meters or appropriate calibration of pumps, etc., based on the specific facility requirements.

Temperature measurements will be made in most instances using conventional thermocouple methods. For hot zone temperatures either chromel-alumel or platinum-platinum/rhodium thermocouples will be used. Measurements made in areas exposed to radiant heat or in the incinerator itself will use radiation shielded thermocouples.

Effluent Gas Composition

Continuous analyzers will be used for several categories of pollutants. The primary purpose of the on-line instrumentation will be to provide process data with which to establish operating conditions for each test. Carbon dioxide (CO_2) and oxygen (O_2) will be monitored to provide the basic data on excess air. Carbon monoxide (CO) and total hydrocarbons (HC) will be monitored to determine maximum combustion efficiency conditions. As chemical indicators, CO and HC each represent different degrees of severity (efficiency) required for complete removal (destruction). It is anticipated that hydrocarbon concentrations will be the basis for determining if adequate destruction is realized during a test.

The $CO_2/O_2/CO$ data will provide the gas composition data used in calculating emission flow rates. Nitrogen oxides (NO_x) will be measured using a continuous analyzer to provide individual NO and NO_2 data. This method is preferred to manual methods, which are labor intensive, would require additional sampling equipment, and would only provide a total NO_x value (as NO_2). Several of the wastes contain significant levels of nitrogen, and nitrogen oxides are a significant, difficult-to-control pollutant.

Analyzer types tentatively selected for each of these species are:

CO_2 - Non-dispersive infrared (NDIR)
CO - NDIR
O_2 - Paramagnetic
HC - Flame ionization detector
NO/NO_2 - Chemiluminesence

3.4.6 Facility Sampling Requirements

It will be necessary to utilize a diverse group of methods in order to obtain samples that are representative of actual test conditions for each test. Each test must be considered individually because no single waste will be destructed in more than one facility, and none of the facilities will test a group of similar wastes. Thus, no highly detailed general plan can be written to cover all test burns, but rather a plan for each facility has been generated as part of the Detailed Plan for Phase II of this program (Volume II). This section discusses the rationale that will lead to the final detailed sampling plan for each facility. Several different compendiums of standard sampling procedures will be utilized on this program including those published by the U.S. Environmental Protection Agency (EPA), American Society for Testing Materials (ASTM), American Petroleum Institute (API), "Standard Methods for the Examination of Water and Waste Water,"* "The EPA Methods for Chemical Analysis of Water and Wastes",** and the methods manual currently being generated at TRW for trace metal sampling, and at ADL for sampling of organic effluents. Acceptable sampling and analysis procedures currently used by the facility operators will be utilized for this program as well. As part of the pre-site survey made at least 1 month prior to the actual facility visit, the test engineer will draw upon this compilation of methods to determine the best adaptation to each facility.

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*American Public Health Association, 13 ed., Washington, D.C., 1971.

**U.S. Environmental Protection Agency, "Methods for Chemical Analysis of Water and Wastes," 1971.

Detailed location of sampling points and any necessary modification of facilities for sampling will be made based on responses received from the facilities and in particular from the pre-site visit.

The program plan is to obtain the best sample consistent with the particular design of each facility. Few if any of the facilities were designed with sampling requirements in mind, and, as a result, some innovation will be required to obtain adequate samples. One example of the certain difficulties to be faced during the program will be the need for establishing confidence that a sample is homogeneous and truly representative of the entire stream. There are likely to be areas of vertical density gradients, velocity fluctuations, and concentration gradients that must be recognized and avoided if possible. When conditions require a sample to be taken under less than optimum conditions, an evaluation of the representative quality of the sample will be initiated at the pretest site survey and continued through the test burn period. It is further anticipated that any error in the data caused by this problem of less than optimum sampling will be well within an accuracy range equal to a factor of two or three, a level which should be acceptable for the purposes of this study. The following discussion describes each general type of thermal destruction facility and the types of samples which will be taken to determine its combustion characteristics.

Most of the facilities to be studied can be generically treated as incinerators. The wet oxidation and pyrolysis destructors are unique from the incinerator units both in terms of the detoxification process and the sampling requirements. A generalized schematic of these three types of facilities is shown respectively in Figures 3-2 through 3-4.

Each of the types will require measurement of input values (waste feed, auxiliary fuel if used, and air) and operating parameters such as temperature and pressure. The incinerator type units will generate effluent

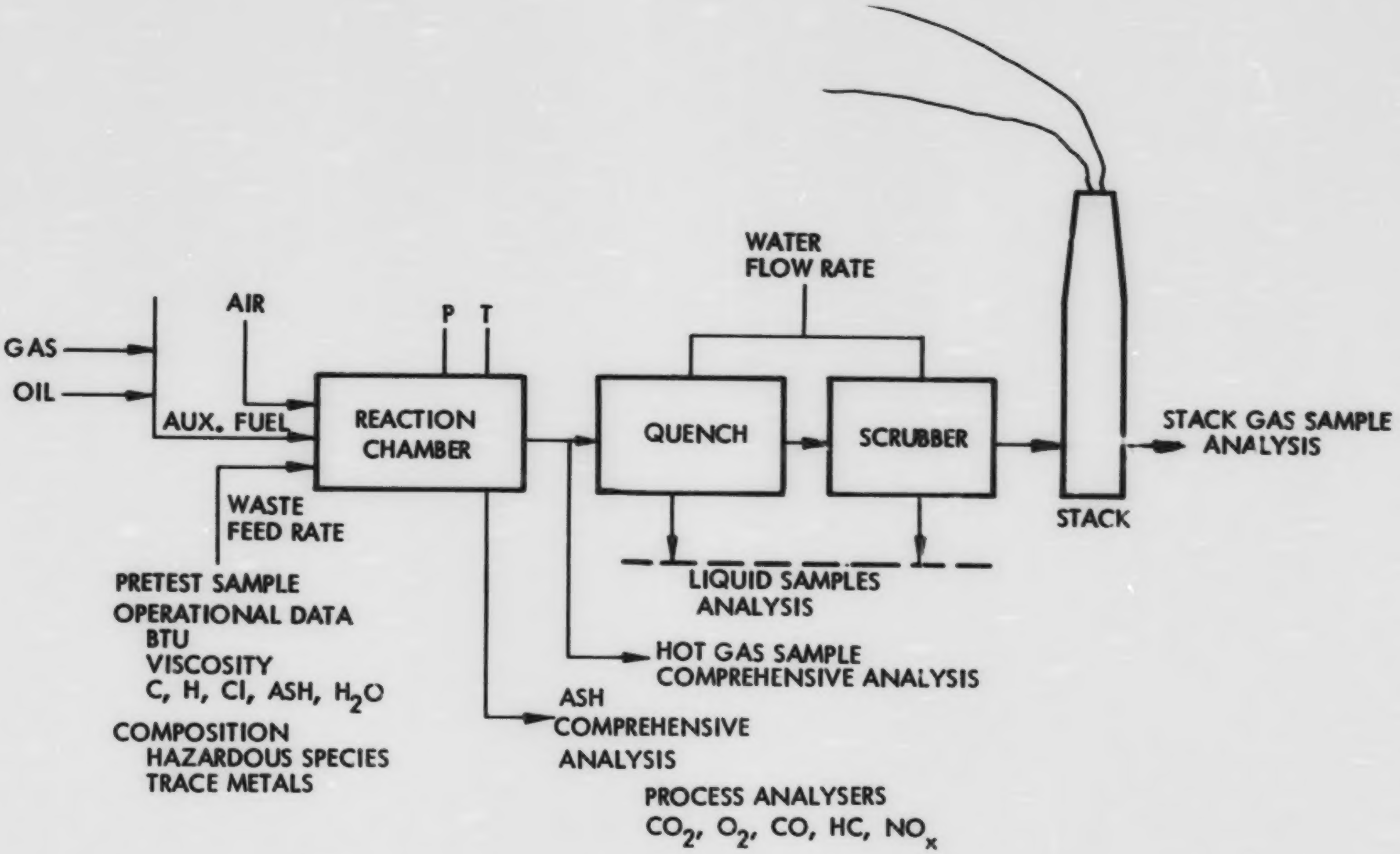

Figure 3-2. Generalized Schematic of Incinerator Facilities

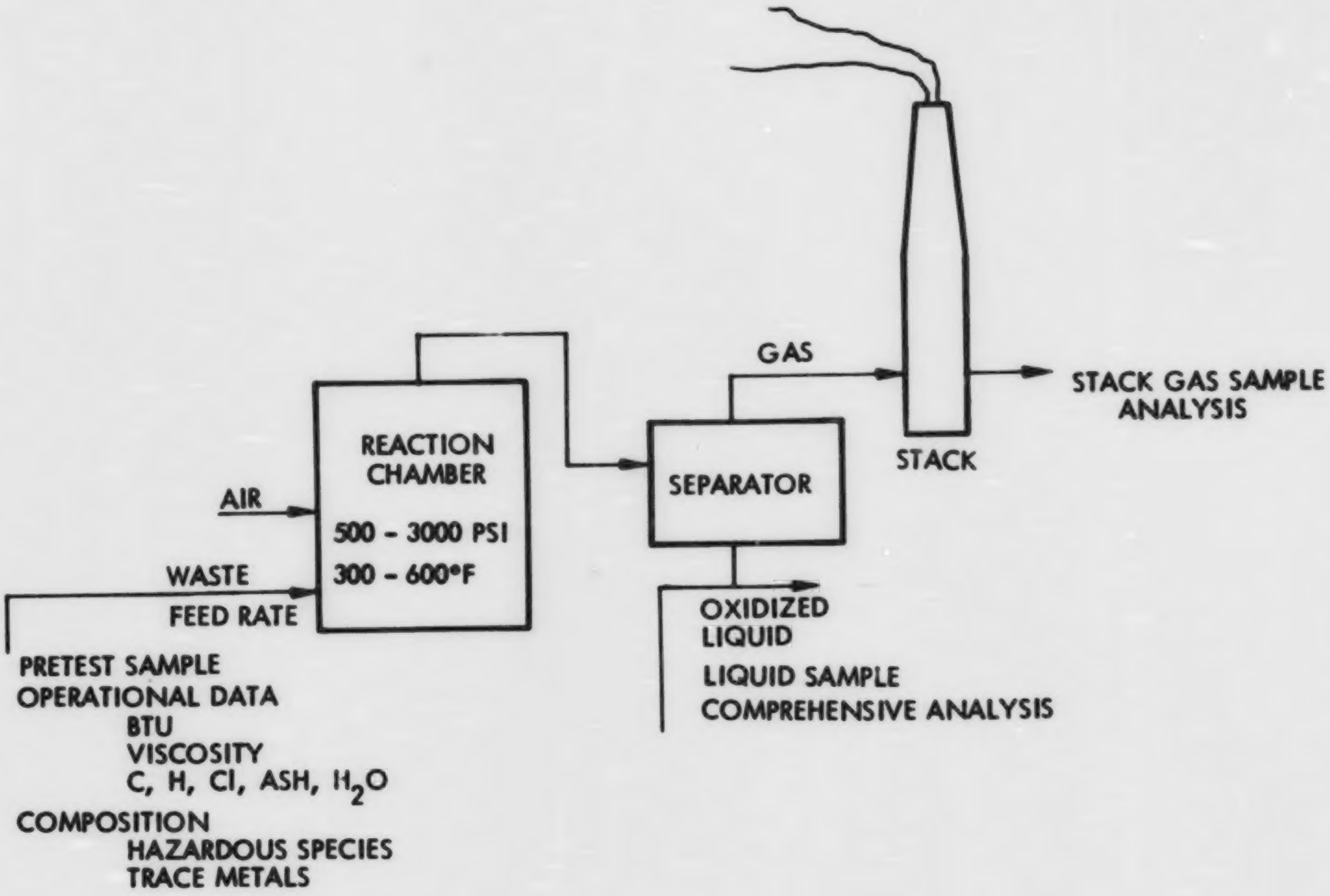

Figure 3-3. Generalized Schematic of Wet Oxidation Facility

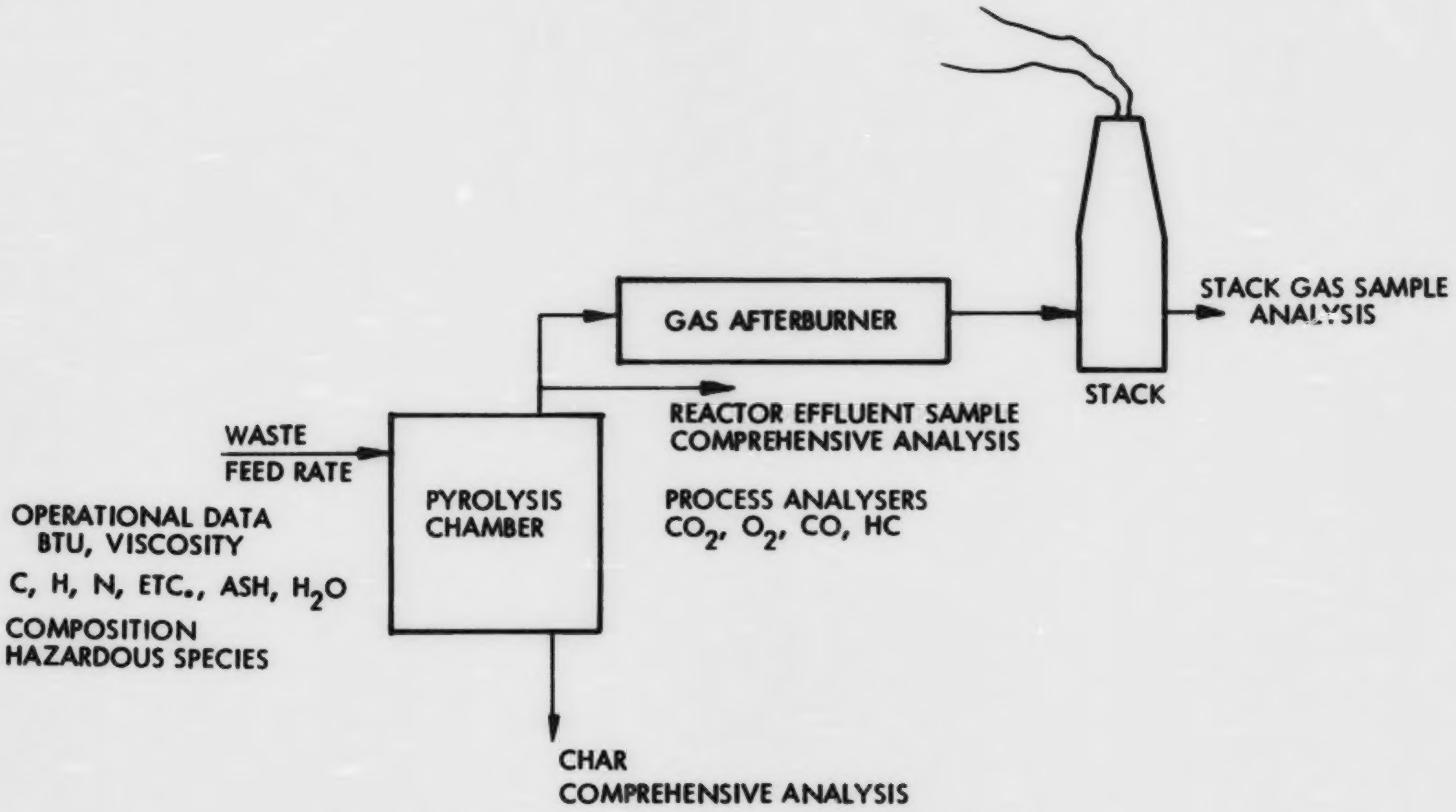

Figure 3-4. Generalized Schematic of a Pyrolysis Facility

samples of which the gaseous effluent from the high temperature zone is the most important; but measurement of the ash, quench and scrubber solutions, and stack gas samples will also be significant. The wet oxidation unit samples will consist primarily of effluent gas and solution. The pyrolysis unit selected for this study will generate a char, which is the principal effluent, and a low heating value gas which is combusted in the afterburner.

Sample sampling detail of each of the facility types to be studied is discussed in the following paragraphs.

Liquid Injection, Rotary Kiln, Fluidized Bed, and Multiple Hearth Facilities

In terms of sample points at a facility, liquid injection, fluidized bed, rotary kiln, and multiple hearth units are quite similar and can be discussed as a unit. The waste feed for the liquid injection incinerators will be obtained from run/surge tanks. If the tank cannot hold the entire amount needed for the test, the individual drums of waste will be the sampling point.

The waste feed samples for the rotary kiln and multiple hearth units will be taken from a bin, conveyor, screw feeder, or ram feeder. The ash or slag residue will be sampled from the ash hoppers for each unit or from the conveyors that fill them. There is not likely to be a significant ash residue from the liquid injection incinerators, but attempts will be made to recover any if access is provided. This is likely to be found in the bottom of any liquid injection firebox.

The reactor effluents are those found in the fire box or in the actual combustion chamber for these units. It is these gases that will provide much of the data with which to determine incinerator destruction capabilies as well as the on-line determinations of hydrocarbons and carbon monoxide. The most desirable location for sampling the reactor effluents is that spot where the combustion gases exit the firebox or final hearth prior to any quench or gas scrubbing hardware. In this way the data obtained will reflect the performance of the incinerator independent of the performance of the scrubber. The final downstream port in the firebox or a port in the duct work leading into the quench/scrubber will be the sample point. All equipment and lines will be cleaned prior to testing of each waste.

Samples taken from the stack gases downstream of quench/scrubbing equipment will be taken at a convenient point prior to being discharged to the atmosphere. These stacks are usually vertical, and a sampling point will be sought near the ground just after the last turn in the duct which directs the gas upward. For practical reasons any sampling port provided in this locale will be used.

Samples of the quench/scrubber water can be taken from several points. Listed in decreasing order or preference for obtaining a composite sample with ease are: (1) holding tanks containing all the solution used in the test, (2) a recirculation tank for solutions being recycled, and (3) pipe through which these solutions are being pumped.

Molten Salt Incinerator

The molten salt incinerator differs from the units described above in that there is no ash residue. It is dispersed throughout the molten salt bed which itself will be sampled. There are several different means for feeding solids all of which have a tap-off for samples. The shredded solids hopper is a preliminary sampling point choice, but the final choice of the sample point for each waste feed will have to await receipt of the waste material and feed system testing.

Hot zone gas sampling for on-line monitoring and comprehensive sampling of the reactor will be taken downstream of the demister unit and upstream of the afterburner. On-line monitors currently used tap the line at this point, and it has been reported that gas composition does not change in passing through the demister. For these reasons it is the preferred point for reactor sampling. The scrubber liquids will be taken from: (1) a recirculation tank for scrubber liquids, or (2) from lines leading to a common waste system.

Catoxid* Process

The B.F. Goodrich Catoxid Process for resource recovery from waste halogenated by-product is the only catalytic oxidation process presently available to this program. In this unit a liquid chlorinated hydrocarbon waste is converted into a gaseous product containing all the chlorine values which are used in an oxychlorination process.

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*Registered trade name.

The liquid waste feed sample will be taken from the recirculating feed tank. Samples of the reactor products containing hydrogen chloride, oxides of carbon, nitrogen and oxygen will be taken downstream of the heat recovery unit. The system is operating under continuous, steady-state conditiins which cannot be easily changed.

Wet Oxidation

The wet oxidation is a departure from the previous destructor types in that there is no firebox sample. The primary samples are condensed liquids and solids taken along with the head gas after the vapor effluent has been condensed (Figure 3-3).

The units to be tested take the waste feed directly from the supplied 55 gallon drums. Therefore, it will be necessary to take the pretest samples from the drums. In one facility, there are two aqueous streams coming directly from the reactor. One stream is the liquid effluent; the other is the condensed vapor which has boiled off the reacting solutions. Presently, there are two separate streams leading to separate water treatment units. These stream samples will be taken at taps leading to the water treatment units. The gas sample will be taken downstream of the condenser. In the second facility the gas sample will be taken from the vapor/liquid separator, as will the liquid samples.

Pyrolysis

Pyrolytic units (Figure 3-4) function to recover useable byproducts by treating wastes under conditions of heat, pressure and limited combustion air. Depending on facility design, various gases, liquids, and solids will be recovered which have value primarily as thermal energy. In order to characterize the pyrolyzer performance, samples of the product gas will be taken as it exits the reactor. All gas samples may be taken downstream of an afterburner if access prior to it is prohibited, or if an appropriate test can be planned utilizing only the one sample. A composite of the char will be obtained as it exits the reactor.

3.4.7 Methods of Sample Collection

Samples of Hazardous Waste Feed

Waste materials for destruction will include organic liquids which may have solids contents up to the point where they become slurries. Sludges and emulsions are also anticipated. Tar-like and wax-like solids will also require sampling along with certain dry, pourable solid flakes, and powders.

A random representative sample of the waste that is to be fed to the various incinerator systems will be sampled by methods that are largely determined by whether the waste feed run tanks or waste feed hoppers are large enough to contain the entire amount of mixed waste feed that will be used for a test burn. Liquid or slurried waste feeds whose total shipment can be held and mixed in the facility run tanks will be sampled from those tanks using a bomb-type or trap-type "thief" as indicated in paragraphs 27 through 29 of ASTM D-270-65, entitled "Sampling Petroleum and Petroleum Products." This approved method is also designated API Standard 2546 by the American Petroleum Institute. The sample contents of the thief will be placed in a brown glass bottle with a Teflon cap that has been specially cleaned, dried and labeled. The head space above the sample will be purged with nitrogen in order to remove atmospheric oxygen. If the run tanks at the facilities are not large enough to contain the total shipment of waste feed to be used in the test burn, representative sampling will have to be performed on the 55-gallon drums which will be used by nearly all of the waste suppliers. About five drums will be required per ton of supplied waste material and for all facilities except perhaps the very smallest, more than five drums of waste feed material will be required for testing. ASTM D-270 requires four drums to be randomly selected from lots of waste material containing between four and 64 drums. A glass dip tube will be used to take samples of approximately 75 milliliters from the upper, middle, and lower third of each sample drum (paragraph 25 of ASTM D-270). All of the 75 milliliter samples from the sample drums will be combined as a composite sample in a clean dry brown glass bottle of 1-liter capacity, sealed with a Teflon-lined cap and appropriately labeled.

Many of the waste feed materials that will be subjected to thermal destruction will be solids, and a similar decision must be made as to whether the entire waste feed can be sampled from one large feed hopper or whether it will be necessary to sample from individual drums of the solid waste. If a composite sample can be taken of the solid waste feed from a bin, hopper or other vessel holding the entire feed, then samples will be taken from random locations about the entire top of the pile, taking material from at least 1 foot below the surface. Paragraphs 34 through 36 of ASTM D-270 call out the procedure. A clean dry wide mouth jar of brown glass will be used to contain the sample. In an alternate method, solids in drums can be sampled by selecting the minimum required four drums at random and taking regular and frequent scoop samples of the stream from the drums as they are dumped into the feed hopper (paragraph 36.4, ASTM D-270).

It is entirely possible that certain wastes supplied to the program will have solidified within the shipping drums and will have become non-pourable. Where facilities are available, attempts will be made to heat the drums to lower the viscosity, but if unsuccessful, this material can be sampled by using a ship's auger to drill into the solid from the top of the drum and through the metal sides if necessary. There are three sections of ASTM D-270 which present the techniques to be used on this type of sample: paragraphs 37 through 40, paragraph 32, or paragraph 36. The physical nature of the waste at the time of sampling will determine which of the above procedures should be used.

Reactor Effluent Sampling

The basic procedures to be used in sampling the reactor effluent at the hot zone are equivalent to those used in the EPA Method 5. However, two particular characteristics of the sampling require modification of the basic method. The first is the requirement for sampling in a zone where temperatures are expected to be in the range of 500° to 1000°C. The second is that, for these particular tests, organic species are expected to predominate the emissions, which will require complex analyses.

The sampling train evolved to solve the temperature problem and optimize the sampling for subsequent analysis is shown schematically in Figure 3-5. The components are a temperature controlled water cooled probe, a particulate filter using a high efficiency fiber filter, a vapor sorbent trap, a series of impingers, and the control module.

The probe is shown in greater detail in an idealized schematic in Figure 3-6. The inner portion of the probe is a conventional thermostated transfer line as in the Method 5 train. The basic probe will be modified by the addition of a water cooled jacket to overcome material failure problems which occur in a hot zone. The cooled probe will also prevent further change in composition of the gas during the sampling process. This procedure has been used successfully in a recent EPA-sponsored program conducted by ADL* at a municipal incinerator and has been used by TRW for similar programs.

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* Described in the Phase I Technical Proposal No. 27033.000, 26 July 1974.

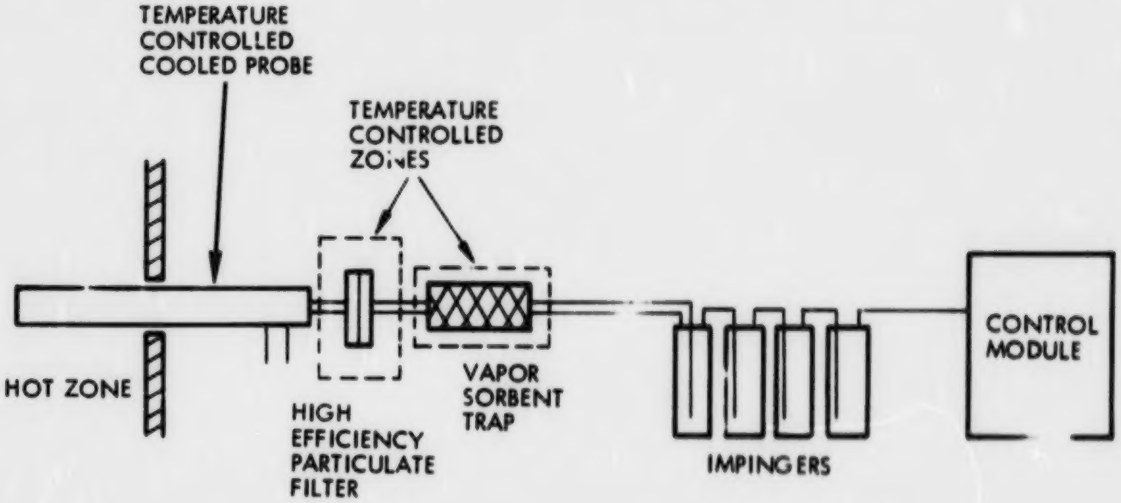
TEMPERATURE CONTROLLED COOLED PROBE
TEMPERATURE CONTROLLED ZONES
HOT ZONE
HIGH EFFICIENCY PARTICULATE FILTER
VAPOR SORBENT TRAP
IMPINGERS
CONTROL MODULE

Figure 3-5. Comprehensive Sampling Train

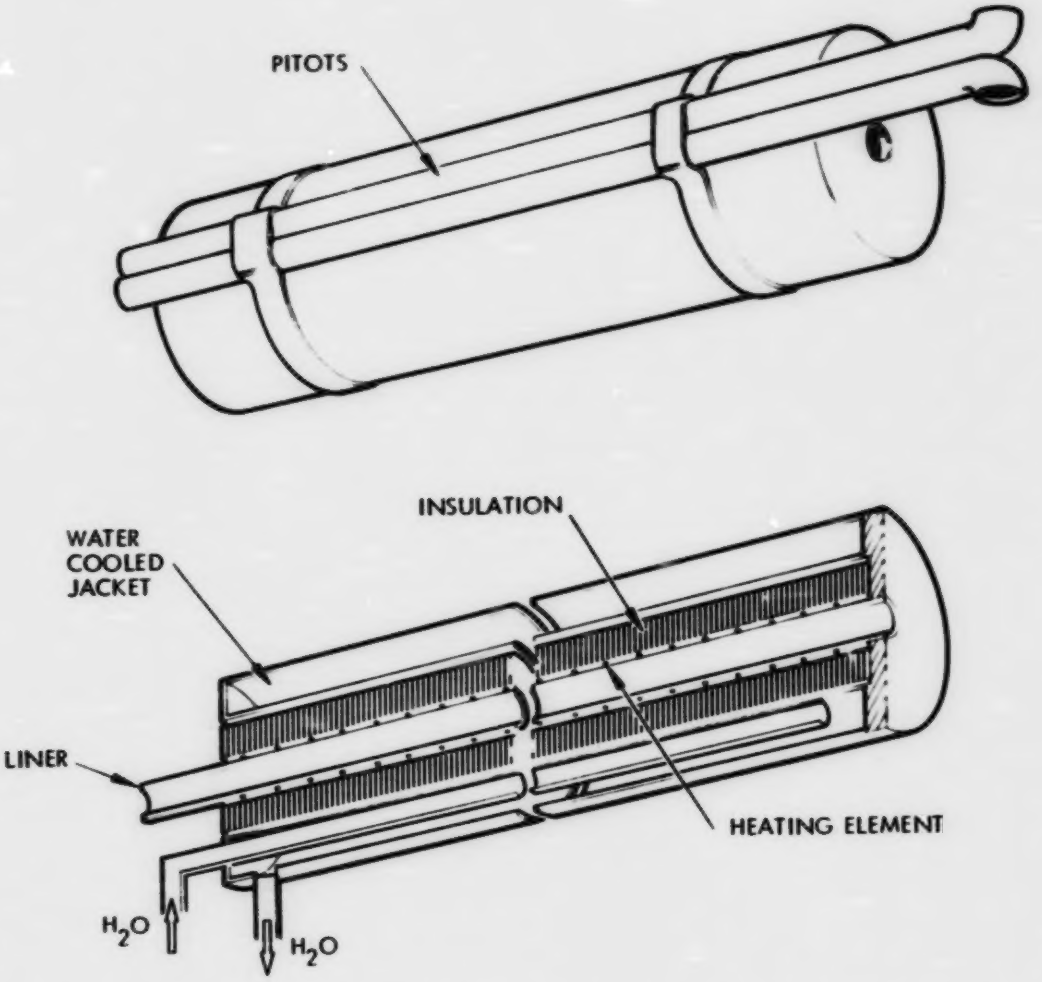

Figure 3-6. Conceptualized Temperature Controlled Cooled Probe

The particulate collection filter will be the standard Method 5 type of high efficiency glass fiber filter. New high purity filters available as a result of recent development programs will be utilized. Organic vapors and other condensible species will be collected on a sorbent trap containing a macroreticular resin such as XAD-2, Chromosarb 102, or TENAX.* These resins have recently been used with a great deal of success in sampling a variety of environments for trace level organic species. They have been used successfully on both ambient air samples and hot gas effluent, such as from diesel engines and jet combustors. The collection and analysis characteristics of these materials are given in greater detail in the sample analysis section (Section 3.4.8).

Finally, a group of wet impingers will be included in the comprehensive sampling train as required to trap special species that have been identified in the preliminary analysis of the waste, and are not expected to be trapped on the filter or in the solid sorbent trap. Specific reagents will be chosen to react with these materials in such a manner that they will be removed from the sample stream and preserved for analysis. The glass impingers will be those commonly found in standard stack sampling trains.

The element referred to as the control console will contain the pump to aspirate the gas sample through the sampling train, and the meters necessary for pressure, volume, and temperature measurements to determine the sample size.

A sampling train in this particular configuration using a solid sorbent trap has not been used extensively, and it will be necessary to verify the validity of this approach. The sample probe temperature will be kept hot enough ($\geq 125^{\circ}C$) to prevent condensation of species. The filter temperature will be kept low to optimize sample stability, but just above the dew point to avoid water condensation and the resultant pressure increase. The vapor sorbent trap will also be heated to avoid condensation and pressure increase.

A laboratory test program will be conducted during the startup period to determine the characteristics of the filter/sorbent trap portion of the train with respect to stability and volatility of collected chemical species. To conduct this evaluation a set of compounds will be placed on the filter and warm gas will be passed through the filter and sorbent trap in sequence. The exposed filter and trap will then be analyzed for the individual species to determine recovery values and distribution of chemicals between train components.

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*Registered trade names.

The set of test compounds will be chosen to be representative of the chemical reactivity types expected from the waste tests. These could include a selection such as a phenol, an aromatic amine, a polynuclear aromatic hydrocarbon, and an aromatic acid. A relatively inert species such as dioctyl phthalate may be used as an internal standard and tracer chemical. In order to better represent actual test conditions the chemicals will be coated on a pre-cleaned flyash sample and then placed on the filter.

An air stream conditioned to 125° to 150°C and containing a few selected reactive species, such as NO and SO_2, will be passed over the "spiked" filter (containing known added compounds) connected in series with a clean sorbent trap. Analysis of the individual species on the filter and sorbent trap will provide data on compound stability and volatility transfer from the filter to the sorbent trap.

Based on previous experience with chemical sampling problems of this type, the proposed method is expected to be adequate for the needs of this program. In the event that significant loss problems are observed with certain species, the sample train will be modified according to the waste being studied. The same components of the train will be used in each case, but the configuration may change in detail.

Ash and Solid Residues

A variety of ash residues as well as slags will be encountered. These may be pourable solids, but slag material may be found in chunks of varying size. A large degree of inhomogeneity can be expected in these sample.

Solid combustion residues such as ash, slag, a portion of the fluidized bed, or molten salt samples will be taken from the respective test facilities used in the Phase II Program. It is possible that some of the other types of destruction facilities, such as liquid injection, will also have some solid residue depending upon the inorganic and solids content of the waste feed. Unless specifically noted, all samples will be placed in clean brown glass, wide mouth jars for storage and transport. For solid residues which weigh up to 2 kilograms (approximately 4 pounds) the entire sample will be taken. Total residues which amount to more than 2 kilograms shall be sampled according to standard random sampling procedures. These residues then can be composited and divided as many times as necessary to obtain the required size sample.

Solid combustion residues from rotary kiln and multiple hearth units will likely be discharged via a conveyor or screw feeder into a bin or hopper. These can be sampled from the bin or hopper by grab sampling techniques for lumpy solids using paragraphs 36 through 38 of ASTM D-270 or ASTM C-311-68 entitled "Sampling and Testing Flyash for Use as an Admixture for Portland Cement Concrete." An alternate method will be to regularly and frequently obtain a portion of a conveyor stream passing by a fixed sampling point.

The two fluidized bed incinerator facilities to be used in Phase II both have overflow ports on the sides of the reactors which have interior openings in the reactors above the resting bed line. During operation, samples of the sand bed can be obtained through these ports. The sand will flow out of the port into a bucket or hopper which then can be sampled after the bed sample cools down.

After a test burn has been completed at the molten salt reactor facility, a sample of the salt bed will be taken. Samples of the salt bed will be obtained both before and after test runs in order to establish good baseline conditions. At least 10 minutes will be allowed to pass from the time that the waste feed is cut off until the salt samples are taken in order to be confident that all destruction that is expected to take place would already have done so. The molten salt reactor at Atomics International has a port for taking the sample. A glass rod is extended through the port into the bed and then removed. The molten salt then freezes on the glass rod, and the sample is chipped or scraped from the glass rod.

Sampling of Scrubber Solutions

All facilities that will be tested in this program will have quenching and/or scrubbing equipment to cool and condition the exhaust gases prior to being released to the atmosphere. This equipment will discharge aqueous streams containing spent scrubber materials, suspended flyash, and other species. Their temperatures will generally be in the range of 70^{o} to $80^{o}C$ depending on individual incineration design. A possible exception to this would be the catalytic oxidation reactor at B.F. Goodrich where the entire reaction stream goes to an oxy-chlorination process, and which is not part of the catalytic oxidation system. All of these quenching/scrubbing facilities are expected to differ widely from one another in design, and subsequently the absolute final details of how to sample will have to be established at the detailed pre-test site survey. The following paragraphs describe the several options that will be available to the test planner in selecting the sampling methodology for obtaining appropriate aqueous samples.

Whenever possible,all aqueous samples will be taken from surge or recirculation tanks immediately after the test in order that the composite samples can be obtained without the extra effort needed for frequent grab sampling or the use of automated sampling equipment. A dip tube or sampling bottle device will be dropped into the recirculation tank and allowed to fill. The contents will be transferred to clean brown glass bottles equipped with PTFE lined bottle caps. Results from preliminary analysis may indicate that an important, unstable species will be found in these samples. In that event a portion of the sample will be taken specifically for that species and the appropriate preservative added. The number of these instances is expected to be low.

Samples will normally be stored in a cool area prior to shipment to the laboratory for analysis. Where it is anticipated that unstable species may be present or where it is uncertain, the organics will be removed by passing the solution through solid sorbent columns containing XAD-2 or

TENAX resins. This operation will remove organics of interest from the water and will preserve them on these resin beds until they can be eluted, concentrated and analyzed back in the lab. The stability of organic compounds once they are absorbed on the column is quite adequate for the purposes of this program. Storage times of 4 mohths with no apparent change for organic ambient air species on these columns have been reported. (See Section 3.4.8 for documentation of these procedures.)

Stack Gas Sampling

The quench/scrubber effluent (stack gas) is comparable to typical streams which have been conditioned in an aqueous stream. Typically they will be warm (70^{o} to 80^{o}C), water saturated, and have light particulate grain loadings. Stack gas samples will in most cases be sampled using the conventional EPA Method 5 procedure. For the purposes of this program, the primary purpose of collecting stack gas samples will be to obtain an estimate of scrubber effectiveness and to be sure that no undesirable emission of hazardous species to the atmosphere occurs. If the presence of a hazardous species is predicted on the basis of preliminary waste characterization, the train will be modified into the configuration for comprehensive sampling in order to search for these hazardous species.

Sample Identification and Coding

A coding system has been devised which will permit all of the expected routine samples to be labeled with a code to completely individualize the sample among the several hundred to be gathered during Phase II. The sample code basis is shown in Table 3-11.

Each collected sample will be assigned a unique designation which will be used to track the sample through the analysis procedures and which will be indicative of the source and type of sample. An example of a typical

Table 3-11. Sampling Codes

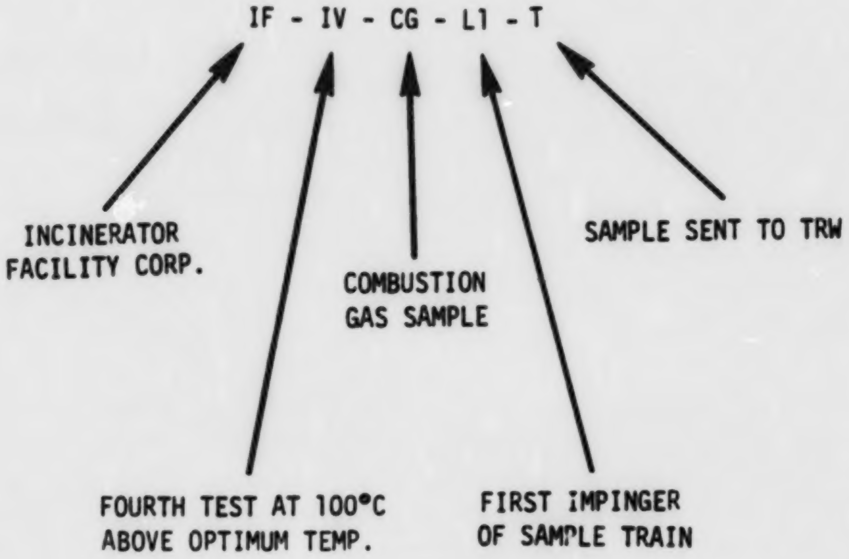
Type or Source of Sample	Code Number or Letter					Interpretation
	XX-					Two letter designation for name of incineration facility (example: AI for Atomics International).
		-I-				Test burn numbers (Roman numerals) for each different set of incinerator operating conditions and waste.
Blended Waste Stream Feed			-BW-(XXXXXXXXXXXX)			Sample of waste in incinerator run tank after mixing. Information in parentheses may be supplied by waste stream manufacturer if in multiple drum lots. Sample composited at site.
Scrubber or Quench Water			-FSW-			Pre-test scrubber solution containing all chemicals to be used and after circulation through scrubber for mixing and cleanout.
			-SSW-			Spent scrubber solution into holding tanks or scrubber run tank composited at site.
				-HT-		Spent scrubber solutions in holding tank (if applicable).
					-1-	Sample of supernatant after 24 hours settling.
					-2-	Sample of holding tank bottoms after 24 hours settling.
Combustion Gases			-CG-			Combustion gas sample from hot zone.
				-PF-		Particulate filter from comprehensive train.
				-ST-		Sorbent trap.
				-L1-		Impinger number (first impinger in train).
				-L2-		Second impinger in train.
				-L3-		Third impinger in train.
				-L4-		Fourth impinger in train.
Stack Gases			-SG-			Stack gases released to atmosphere.
				-PF-		Particulate filter from sampling train.
				-ST-		Sorbent trap from sampling train.
				-L1-		First impinger.
				-L2-		Second impinger.
				-L3		Third impinger.
				-L4-		Fourth impinger.
Residues from the Incinerator, Reactor or Combustion Vessel			-R-			Ash, slag, dust, or portion of molten salt, composited at site.

ADDITIONAL CODE SUFFIXES

-A-	Sample to be Sent to ADL by TRW for Cross Check.
-T-	Sample to be Sent to TRW by ADL for Cross Check.
-C-	Extra Contingency Sample.
-SS-	Aqueous Samples Extracted with Solid Sorbent.

sample code for an impinger solution obtained from the Comprehensive Sampling Train is:

EXAMPLE OF SAMPLE IDENTIFICATION CODING


IF - IV - CG - L1 - T
INCINERATOR FACILITY CORP.
COMBUSTION GAS SAMPLE
SAMPLE SENT TO TRW
FOURTH TEST AT 100°C ABOVE OPTIMUM TEMP.
FIRST IMPINGER OF SAMPLE TRAIN

3.4.8 Sample Analysis Procedure

Categories of Samples and Chemicals to be Analyzed

The analytical program will involve the analysis of feedstock samples including both the waste stream being tested and any auxiliary fuel used to balance combustion requirements. Effluent samples will consist of the various gas, liquid, and solid samples collected with the sampling systems from the appropriate points in the facility. These samples will be primarily:

- Reaction chamber gas phase effluent sampled in one or more of the following ways:
  - Particulate collected on filters
  - Vapor collected on adsorbents
  - Impinger

- Ash or slag
- Incinerator scrubber and/or quench spray solutions
- Stack gas samples similar to those for incinerator effluent
- Vapor and solution samples from wet oxidation processes
- Product stream samples from pyrolysis processes.

The analysis of each sample will be directed primarily at determining the concentration of:

- Principal chemical species believed to be hazardous
- Primary decomposition products of the waste (CO_2, HCl)
- Secondary decomposition products (partial oxidation or pyrolysis product)
- Other species - analyzed chemical species to be compared against documented lists of hazardous chemicals.

The principal species to be analyzed will be those known to be in the waste feedstock and believed to be hazardous. In some cases these will represent discrete chemical species such as phenol, dichlorophenols, and TNT. In other cases, such as those involving the incineration of tarry wastes from Captan, rubber manufacturing and TDI, the analyses may have to be restricted to a general class of chemical species such as total organic chloride, total aromatic amine, etc.

The primary decomposition products are defined as those which would result from the complete destruction of the waste streams under the normal operating conditions of the units being considered. For the hazardous streams containing only C, H, O the primary decomposition products are simply CO_2 and H_2O, and the analyses of primary decomposition products will be only for CO_2. For chlorinated species HCl would be the primary reaction product while those such as Malathion would lead to phosphates, and various nitrogen containing wastes (TDI, TNT) would give rise to NO_x. Each waste would be carefully studied from both an experimental and theoretical point of view before testing in order to determine the types of analyses which should be conducted for each of the species of interest.

Secondary decomposition products are meant to represent those chemical species which are partial decomposition products of the hazardous waste which would still be considered hazardous. Examples are dichlorophenol from DDT decomposition and hydrogen cyanide from TDI. Several (usually 1 to 4) species such as these can be expected from each waste under consideration. The appropriate analytical procedures will then be used to determine the concentration of as many of these compounds as required. In some cases class type analyses may again be preferred depending both on the nature of the waste and the toxicity of the anticipated products.

In addition, samples will be analyzed for a number of other species. During any combustion process a number of chemical species occur, usually in low concentration, which are not readily predictable in advance. A search for these "other" species will be made using a sequence of survey techniques capable of detecting organic and inorganic species. It is anticipated that analyses accurate to within a factor of 2-3 for these species will be adequate for this task because the concentrations will most likely be lower than levels recognized to be hazardous. However, because of their low concentration levels, it will be particularly important in these cases to compare the results obtained during the test burn to the initial background data found for the facility before the burn. This will assure that these "other" species are at higher concentrations than those formed from combustion of any supplementary energy source.

Sample Preparation

The manner in which each of the collected samples will need to be treated prior to analysis will depend on the specific waste studied and analysis to be conducted. Preparation requirements are different also for organic and inorganic/metallic species. Samples collected for gas phase analysis will, in most cases, be analyzed directly without sample pretreatment. For the determination of the hazardous species and the secondary decomposition products in the liquid, vapor (sorbent) and solid (particulate, ash) samples some pre-treatment will most likely be necessary.

The method of pretreatment depends on the types of species known or suspected to be present. Survey or screening analyses for species may be used on the samples as received. The results of the survey analyses would then help to define the methods of pretreatment and analysis.

A number of sample preparation procedures are well established and will be chosen based on the analysis to be conducted. The EPA Freon (formerly hexane) extraction procedures used for "oil and grease" in water samples(2) will be appropriate for a number of the samples to be encountered in this study. Alternatively, the procedure involving adsorption from solutions onto resins, such as XAD-2, published by Junk, et al.,(3) is widely used in many laboratories involved in the analysis of environmental samples and may prove beneficial for these studies. The validity of this technique for a variety of compound classes can be seen from a review of the data shown in Table 3-12. In particular, use of this method improves the detection limits for trace level organics and will prevent decomposition.

A variety of specific methods are practiced for the extraction of organic species prior to analysis. Most of these techniques work well, but it should be verified that: (1) the procedures do not introduce artifacts by way of solvent impurities, (2) volatility losses do not occur, and (3) that the species of interest do not undergo change during the sample preparation procedure. Many recent studies have shown that complex trace level environmental samples do not change their chemical form due to oxidation or other reactivity as rapidly when maintained in a dilute solution or fixed on a stabilizing adsorbent. For the analysis of certain species it will be necessary to add the appropriate stabilizing reagent just after collection. For example, solutions are usually acidified to prevent the loss of trace metals; samples to be analyzed for fluoride and cyanide are usually adjusted to pH 10; where bacteria may be a problem, bacteriocides such as mercury and copper solutions are usually added to prevent the decomposition of species such as nitrite and phenols.

For the extraction of particulate samples pursuant to the analysis for organic species, pentane, methylene chloride, and diethyl ether have

Table 3-12. Over-All Recovery Efficiency of the Porous Polymer Method of Analysis for Organics in Water at the 10- to 100-ppb Level (Reference 1)

Compounds Tested	Efficiency (% Recovery)
Alcohols	
Hexyl	93
2-Ethylhexanol	99
2-Octanol	100
Decyl	91
Dodecyl	93
Benzyl	91
Cinnamyl	85
2-Phenoxyethanol	102
Aldehydes + ketones	
2,6-Dimethyl-4-heptanone	93
2-Undecanone	88
Acetophenone	92
Benzophenone	93
Benzil	97
Benzaldehyde	101
Salicylaldehyde	100
Esters	
Benzyl acetate	100
Dimethoxyethyl phthalate	94
Dimethyl phthalate	91
Diethyl phthalate	92
Dibutyl phthalate	99
Di-2-ethylhexyl phthalate	88
Diethyl fumarate	86
Dibutyl fumarate	92
Di-2-ethylhexyl fumarate	84
Diethyl malonate	103
Methyl benzoate	101
Methyl deconate	95
Methyl octanoate	98
Methyl palmitate	70
Methyl salicylate	96
Methyl methacrylate	35
Polynuclear aromatics	
Naphthalene	98
2-Methylnaphthalene	95
1-Methylnaphthalene	87
Biphenyl	101
Fluorene	84
Anthracene	83
Acenaphthene	92
Tetrahydronaphthalene	62
Alkyl benzenes	
Ethylbenzene	81
Cumene	93
p-Cymene	92
Acids (acidified)	
Octanoic	108
Decanoic	90
Palmitic	101
Oleic	100
Benzoic	107
Phenols	
Phenol	40
o-Cresol	73
3,5-Xylenol	79
o-Chlorophenol	96
p-Chlorophenol	95
2,4,6-Trichlorophenol	99
1-Naphthol	91
Ethers	
Hexyl	75
Benzyl	99
Anisole	87
2-Methoxynaphthalene	97
Phenyl	91
Halogen compounds	
Benzyl chloride	88
Chlorobenzene	95
Iodobenzene	81
o-Dichlorobenzene	88
m-Dichlorobenzene	93
1,2,4,5-Tetrachlorobenzene	74
a-o-Dichlorotoluene	96
m-Chlorotoluene	80
2,4-Dichlorotoluene	71
1,2,4-Trichlorobenzene	99
Nitrogen compounds	
Hexadecylamine	94
Nitrobenzene	91
Indole	89
o-Nitrotoluene	80
N-Methylaniline	84
Benzothiazole	100
Quinoline	84
Isoquinoline	83
Benzonitrile	88
Benzoxazole	92
Pesticides + herbicides	
Atrazine	83
Lindan	95
Aldrin	47
Dieldrin	93
DDT	96
DDE	81

proven especially useful. These solvents have the range of solvent polarity required for extraction, are readily volatilized for the concentration of samples and may be purified (distillation and sorbent filtration) so that contamination is kept to a minimum. For samples containing metallic or inorganic components and thus to be analyzed by atomic absorption, the hydrochloric/nitric acid digestion procedures described by Thompson(4) will be appropriate.

Analytical Methods

The analytical methods required for this program call for the full spectrum of capabilities to analyze elemental and molecular species, inorganic and organic chemicals using quantitative methods for selected chemicals and survey techniques to determine the composition of samples.

A few species of environmental concern have been recognized by appropriate agencies, notably the EPA. Methods have been recommended for their analysis. Most of these are basically inorganic species such as Hg, Be, NO_x, SO_2, H_2SO_4, H_2S, F and CO. However, it is crucial to recognize that this program calls for the examination of a selection of industrial wastes representing a wide variety of chemical species which are principally organic chemicals and for which specific methods have not yet been recommended.

Analytical procedures recommended by U.S. EPA, ASTM, and NIOSH will provide valuable guidelines for the samples to be encountered in these studies. Another valuable resource will be the analytical procedures used by the industries to characterize their waste stream. Several recent reviews(5,6,7,8) also provide useful guidance in the selection of analytical methods.

Prior to a discussion of the development of a general analytical scheme to be used for all samples, a review of most of the techniques which will be appropriate for use in this program follows.

Techniques are needed which will characterize the elemental composition of a sample as well as determine specific compounds present in mixtures. These data may be obtained from a variety of spectroscopic and other analytical techniques.

In Table 3-13 several techniques which have been used successfully on samples related to other environmental programs are listed along with an indication of whether their primary utility is to provide elemental composition or compound identity data and whether they are primarily useful for these purposes in a qualitative survey or quantitative analysis mode. It is recognized that some methods can provide adequate quantitative data in a survey mode, but the purpose of the table is to indicate the primary utility of a method. Each of the techniques most appropriate for environmental samples is discussed briefly below to highlight advantages, limitations, etc.

Mass Spectrometry

1) Spark Source - Spark source (SSMS) excitation is usually used for elemental analysis of environmental samples because of the relatively uniform ion formation for all elements.(6,9,10) Sample preparation including removal of organic matter and mixing with graphite to prepare electrodes is required prior to analysis. Standards prepared in a matrix similar to the sample are required for quantitative analysis, but even then precision is poor.(7) The recent collaborative testing study conducted by von Lehmden, et al.(8) provides an excellent comparison of SSMS with other techniques for determination of elements. Their work also points out the wide variation in data still obtained within a given technique and between techniques. One major advantage of this technique is the uniform sensitivity for most of the elements. This characteristic improves the overall accuracy in survey-type analyses.

2) High Resolution - High resolution and specific ion detection mass spectrometric techniques (HRMS) used in conjunction with data acquisition and processing have the ability to identify elements and compounds in the 10^{-9} to 10^{-12} gram range with reasonable freedom from false positive results.(5) Relatively uniform high sensitivity is obtained for all materials which are volatilizable at source temperatures and pressure. The technique is restricted to volatile material and usually excludes low polymers or salts, etc. There is a tremendous amount of data present in the HRMS of an organic environmental mixture, and much of the value of the data lies in

Table 3-13. Analytical Techniques

Technique	Analysis Categorization				
	Acronym	Elements	Compounds	Survey	Quantitative
Spark Source Mass Spectroscopy	SSMS	X		X	
Optical Emission Spectroscopy	OES	X		X	
X-Ray Fluorescence					
- Dispersive (wavelength)	XRF	X		X	X
- Energy Discriminating	EDXRF	X		X	
Neutron Activation Analysis	NAA	X		X	
Atomic Absorption Spectroscopy	AAS	X			X
Flame Emission Spectroscopy	FES	X			X
Anodic Stripping Voltammetry	ASV	X			X
Optical Microscope	OM	X	X	X	X
Scanning Electron Microscopy	SEM	X	X	X	
Transmission Electron Microscopy	TEM		X	X	
Electron Diffraction	TEM/ED		X	X	
X-ray Diffraction	XRD		X	X	
Infrared Spectroscopy	IR		X	X	
Ultraviolet Spectroscopy	UV		X		X
Mass Spectrometry					
- Low Resolution	LRMS		X	X	
- High Resolution	HRMS		X	X	
Chromatography					
- Thin Layer	TLC		X	X	
- Liquid	LC		X	X	X
- Gas	GC		X	X	X
Combustion Analysis	C, H, etc.	X			X
Chemical Analysis					
- Anions	-		X		X
- Specific Analytes	-	X	X		X
Continuous Analyzer	-		X		X

evolving unique means of data reduction. A scheme based on an analysis of the chemical types present in a sample has recently been reported by Caragay, et al.(11) HRMS appears to have its greatest promise in determining the elemental composition of trace organic constituents in a sample and in verifying the absence of certain sought species.

3) Low Resolution - Low resolution mass spectrometry is perhaps the single best technique to use to examine an unknown sample to determine the nature of the organic compounds present. In cases of simple mixtures, the LRMS data may be sufficient for compound identification, especially using modern file-searching techniques.

4) Combined Gas Chromatography - Mass Spectrometry - CC/MS - Gas chromatographic separation with mass spectrometric detection makes possible the identification of overlapping gas chromatographic peaks in the 10 to 100 nanogram (10^{-9} gram) sample size range.(12) Quantification with this technique may be a problem.(13) An example of the power of this technique can be seen in the identifications achieved in an ambient air sample, Table 3-14.

- Atomic Absorption (AA) - Flame and flameless atomic absorption are the most widely used techniques when information on one or a few specific elements is required. Seventy elements may be determined; simultaneous multi-element detection, however, is difficult. The element to be determined must be in solution or suspension. Significantly lower detection limits have been obtained with flameless atomic absorption methods, which also make possible the analysis of solid samples.(12) However, the precision of non-flame methods is much worse and interferences have not been studied sufficiently.

- Atomic Emission

  1) Flame Sources - Lower sensitivities than those obtainable by flame atomic absorption and fluorescence techniques may be obtained for certain elements by flame emission methods.(15,16,17) Simultaneous multi-element analysis is possible, since a separate source is not required for each element (or groups of a few elements) as in atomic absorption. However, flame emission methods are critically dependent on flame conditions, and optimum excitation conditions vary for different elements. Many modern AA instruments have flame emission capability, and it is likely that such hybrid instruments may be required for situations calling for the widest possible scope at the highest possible sensitivity.(14)

Table 3-14. Compounds Identified by GC-MS in an Ambient Air Sample Collected on Tenax Adsorbent (Reference 16)

GC Peak Number	Compound	GC Peak Number	Compound
1.	isobutene (tent)	54.	limonene
2.	n-pentane	55.	1,3,5-trimethylbenzene
3.	2,3-dimethylbutane	56.	isobutylbenzene
4.	ethylene oxide (tent)	57.	1-methyl-2-ethylbenzene
5.	n-hexane	58.	C_4-benzene
6.	methylcyclopentane	59.	C_{12} branched alkane
7.	2-methylhexane (tent)	60.	dimethylethylbenzene
8.	3-methylhexane	61.	1,2,4-trimethylbenzene
8.	2,4-dimethylpentane (tent)	62.	1,2-diethylbenzene
10.	n-heptane	63.	n-dodecane
11, 12.	heptene isomers	64.	methylpropylbenzene
13.	C_8 branched alkane	65.	n-butylbenzene
14.	2,3,3-trimethylpentane	66.	1,2,3-trimethylbenzene
15.	3-methylpentane	67.	dimethylethylbenzene
16.	n-octane	68.	methylpropylbenzene
17.	C_9 branched alkane	69.	methylvinylbenzene
18.	benzene	70-72.	dimethylethylbenzenes
19, 20.	C_9 branched alkanes	73.	dichlorobenzene
21.	2-methyloctane	74.	dimethylethylbenzene
22.	C_9 branched alkane	75.	methyldiethylbenzene (tent)
23.	chloroform	76.	n-tridecane
24.	n-nonane	77.	benzaldehyde
25.	C_{10} branched alkane	78-80.	C_5-benzenes
26.	toluene	81.	methylindane
27.	tetrachloroethylene	82.	C_{11} branched alkane
28-34.	C_{10} branched alkanes	83.	tetramethylbenzene
35.	n-decane	84.	methylindane
36.	C_{11} branched alkane	85.	ethylisopropylbenzene (tent)
37.	ethylbenzene	86.	n-tetradecane
38.	C_{11} branched alkane	87.	p-tolualdehyde
39.	p-xylene	88.	m-tolualdehyde
40.	m-xylene	89.	acetophenone
41-45.	C_{11} branched alkanes	90.	o-tolualdehyde
46.	o-xylene	91.	C_{15} branched alkane
47.	methyldethylbenzene (tent)	92.	n-pentadecane
48.	C_{11} branched alkane	93.	methylacetophenone isomer
49.	n-undecane	94.	naphthalene
50.	propylbenzene+C_{12} branched alkane	95.	methylacetophenone isomer
51.	styrene	96.	n-hexadecane
52.	1-methyl-3-ethylbenzene	97.	methylnaphtahlene
53.	C_{12} branched alkane	98.	MW=140 compound

2) Electric Excitation and Plasma Sources - The rapid, sensitive, and simultaneous multi-element capabilities of conventional emission spectrographic techniques (e.g., D-C arc, OES) have resulted in the extensive use of these techniques for obtaining most of the data on the elemental composition of airborne particulates. Carefully prepared standards are required for quantitative analysis. Precision is generally poor. Detection limits with high-frequency plasma sources are lower than flame atomic absorption or flame and electrical excitation emission limits.(7,18)

- X-ray Fluorescence (XRF) - All elements of atomic number >11 can be analyzed by XRF, although satisfactory data are lacking for elements of atomic number <20.(13) Quantitative comparisons of energy discriminating and wavelength dispersive techniques have been published.(19) XRF is dependent on particle size effects and sample thickness. For airborne particulate analysis, XRF works best when samples are deposited on surfaces. Only nanograms of elements/ cm^2 of deposit are required.(13) Little or no sample pretreatment is required, and the technique is non-destructive.

- Diffraction Methods

    1) Electron Diffraction - This technique used in conjunction with a transmission electron microscope is extremely powerful for crystal identification when only minute amounts of solid are available. However, extensive sample preparation is necessary, and the method is not likely to be viable for most environmental samples. One severe problem is that many analyses are necessary to adequately ensure representation of a heterogeneous sample.

    2) X-ray Diffraction - This method is very powerful for the positive identification of crystalline species. Computer programs have recently been written which allow the simultaneous identification of up to 10 compounds in a mixture, if the patterns of those compounds are present in the data file. Unfortunately, many environmental samples suffer the problem of having compounds present in amorphous forms and at various degrees of hydration. While the technique is sensitive and precise, it will probably only be applicable to a limited range of samples.

- Infrared Spectroscopy - IR is a general technique for group type characterization of samples. Most organic species and many inorganic species of interest should have an absorption frequency in the normal IR range. The technique is widely available in most laboratories and is capable of detecting less than 10 micrograms of many species with modern attachments. The method is most attractive for its nondiscrimination and assurance that every major component of the sample will be represented in the spectrum. Species present at less than 5 to 10 percent in the mixture will generally not be detected. Combustion source samples which are black will suffer from low transmission and resolution because of black-body adsorption effects. However, the new Fourier transform technology has helped overcome some of these problems. An example of the components observed by Cunningham, et al.(20) on ambient particulate are shown in Table 3-15.

- Ultraviolet Spectrosopy - UV is primarily a quantitative tool to be used for the measurement of the amount of a species present either directly, after separation, or through color development with a suitable reagent. It is still considered by many to be the only unequivocal method for distinguishing the various polynuclear aromatic hydrocarbon carcinogens, after they have been isolated by chromatographic means.

- Chromatography - Thin Layer (TLC), Liquid (LC) and Gas (GC) - Each of these chromatographic techniques is an indispensable tool in the identification of environmental samples. Choice between the methods is dictated primarily by the characteristics of the sample and the data required. LC methods and especially the modern high pressure (HPLC) techniques and GC have equivalent speed and resolving power for mixtures. While GC requires volatility, the LC method will work with salts and other non-volatile components. A variety of good detectors are available for GC including halogen, nitrogen and sulfur and phosphorus, specific flame modifications, and mass spectrometry. LC is conducted primarily with a UV detector and so restricts its general utility although some recent reports indicate that LC-MS may become a reality in the near future.

- Combustion Analysis - Classical combustion analysis for the determination of elements such as C, H, N, S, etc., requires large amounts of sample (1 to 50 mg) compared with the instrumental methods. However, it is probably the best means for obtaining the data which will allow one to do a total mass balance analysis of a sample. This could be supplemented by an ignition analysis (loss on ignition at 550°C, volatiles content) for inorganic content, but this latter method suffers from inaccuracies in unknown environmental samples.

Table 3-15. Infrared Spectroscopic Analysis of Ambient Particulate (Reference 20)

Listing of Assigned Infrared Bands Observed in Particulate Samples			
Frequency, cm^{-1}	Assignment		
	Species	Normal mode[a]	Designation
3140	NH_4^+	v_3	a1
3020	NH_4^+	$v_2 + v_4$	a2
2920	Hydrocarbon (C-H)	v_3	e1
2860	Hydrocarbon (C-H)	v_1	e2
2800	NH_4^+	$2v_4$	a3
1768	NO_2^-(bulk)	$2v_2$	d1
1720	NH_4^+(halide)	$v_4 + v_6$	a4
1620	H_2O	v_2	f
1435	CO_3^{2-}	v_3	g1
1400	NH_4^+	v_4	a5
1384	NO_3^-(surface)	v_3	c
1360	NO_3^-(bulk)	v_3	Overlapped[c]
1190	PO_4^{3-}[b]	v_3	k1
1140	PO_4^{3-}[b]	v3	k1
1120	PO_4^{3-}[b]	v3	k1
1110	SO_4^{2-}	v_3	b1
1035	SiO_4^{4-}	v_3	h1
980	SO_4^{2-}	v_1	b2

[a] Spectroscopic designation of vibrational motion after Herzberg (1964).

[b] Assignment uncertain.

[c] This band is overlapped by bands c and a5.

Table 3-15. Infrared Spectroscopic Analysis of Ambient Particulate (Reference 20) (Continued)

Listing of Assigned Infrared Bands Observed in Particulate Samples			
Frequency, cm^{-1}	Assignment		
	Species	Normal mode[a]	Designation
880	CO_3^{2-}	v_2	g2
840	NO_3-(bulk)	v_2	d3
800	SiO_4^{4-}	v_1	h2
780	SiO_4^{4-}	v_1	h3
728	CO_3^{2-}	v_4	g3
670	PO_4^{3-}[b]	v_2	k2
627	PO_4^{3-}[b]	v_2	k2
620	SO_4^{2-}	v_4	b3
600	PO_4^{3-}[b]	v_2	k2
470	SiO_4^{4-}	v_4	h4

[a] Spectroscopic designation of vibrational motion after Herzberg (1964).

[b] Assignment uncertain.

- Anion Measurements - For a screening program of the type in which an accuracy of a factor of 2 or so is acceptable for the analysis of samples of widely varying composition, the use of specific ion electrodes is strongly recommended wherever practicable. Since the electrodes give a (generally) linear response over several orders of magnitude, the need for further sample manipulation of off-scale samples [i.e., dilution (taking a different aliquot) changing cells] such as is experienced in narrow bandwidth measurement techniques (i.e., colorimetry, titrimetry) is eliminated.

This is especially true for the measurement of ammonium ion where a distillation step is generally required prior to colorimetery. Although not an anion, ammonia can be measured as follows:

NH_3 - Air gap electrode, dissolve sample in water, adjust pH to 11 and measure. Detect 0.8 microgram NH_3/5 milliliter solution (10^{-5} Molar)

Techniques for specific anions are given in Table 3-16.

- Colorimetric or Spectrophotometric Methods

  A variety of techniques are available both for specific and class type analysis. Most involve the use of reagents to introduce specificity and increase sensitivity. The solution analyses are usually carried out in the ultraviolet-visible region of the spectrum. Some examples are the molybdate reaction for determination of phosphates, barium chloranilate procedure for sulfate and 2,4-dinitro phenylhydrazone reaction for aldehydes and ketones.

- Continuous Analyzers

  For a few selected species, continuous analyzers are available which have good specificity, sensitivity and reliability. Examples of analyzers relevant to this study are the nondispersive infrared (NDIR) instruments for CO and CO_2, chemiluminesence for NO and NO_2, and the flame ionization detector for hydrocarbons. Use of continuous analyzers on-line during the test will increase detection sensitivity in some cases and solve sampling problems in others. The use of such analyzers wherever possible decreases manpower requirements involved in collecting additional samples such as is the case for the nitrogen oxides.

Analytical Scheme

From a consideration of the techniques presented above a generalized analytical scheme (Figure 3-7) has been developed which should provide the required information in the most effective manner.

The scheme depicts two branches, one where the compounds or elements to be analyzed are already known, and the other a survey category where the composition of the sample must be analyzed prior to final analysis.

Table 3-16. Specific Anion Measurement Methods

Ion	Measurement Method	Minimum Mass Measured	Interferences/Remedies
F^-	Dissolve in dilute acid, addition of complexing buffer, measure with F^- selective SIE	1 µg F/5mℓ solution (10^{-5} $\underline{M}$)	Large excess of Al, Si or Fe may require alkaline fusion and acid distillation, but straight dissolution probably OK for screen
Cl^-	Dissolve in 1 $\underline{M}$ HNO_3 and evaporate to 3 $\underline{M}$ (1/3 volume). Redilute. Measure with Cl^- SIE	30 µg Cl/10 mℓsolution (10^{-5} $\underline{M}$)	Evaporation mandatory to remove Br^-, I^- and $S^=$ which are serious pos. interferences
Br^-	Dissolve in dilute acid, add H_2O_2 and boil. Measure with Br^- SIE	4 µg Br/5 mℓ solution (10^{-5} $\underline{M}$)	H_2O_2 removes $S^=$ and I^- which are positive interferences
I^-	Dissolve in dilute acid, measure directly with I^- SIE	0.6 µg I/5 mℓ solution (10^{-6} $\underline{M}$)	S eliminated by acidification
CN^-	Dissolve in alkaline solution, add $Pb(NO_3)$. Measure with CN^- SIE	1 µg CN/5 mℓ solution (10^{-6} $\underline{M}$)	Pb precipitates $S^=$ and I^- which are positive interferences

Table 3-16. Specific Anion Measurement Methods (Continued)

Ion	Measurement Method	Minimum Mass Measured	Interferences/Remedies
NO_2^-	Dissolve in aqueous solution, adjust to pH 1.7 and measure with N oxide air gap electrode	2 µg NO_2/5 mℓ solution (10^{-6} M)	Weak, volatile acid (e.g., acetic, HF?) may interfere. Some amines and reducing agents (e.g. $SO_3^=$) react with HNO_2
NO_x^- ($NO_3^- + NO_2^-$)	Dissolve in water, make alkaline and pass through Cd reductor column. Then acidify and measure as NO_2^-.	2 µg NO_x/5 mℓ solution (10^{-5} M)	Same
NO_3^-	Dissolve in water and measure with NO_3 SIE	30 µg NO_3^-/5 mℓ solution (10^{-4} M)	I^-, Br^- are positive interferences as is a 50X excess of $SO_4^=$
$S^=$	Dissolve in water, make alkaline, measure with $S^=$ SIE	0.2 µg S/5 mℓ	Electrode poisoned by more than 0.1 µg Hg
$SO_3^=$	Dissolve in water (acidified ?). Acidify to pH 1.7 and measure with SO_2 selective air gap electrode	3 µg SO/5 mℓ	Weak, volatile acids (e.g., acetic) are positive interferences. HNO_2 will oxidize SO_2
$SO_4^=$ (SO_x^-)	Colorimetric via Ba Chloranilate after ion exchange	1 - 2 µg SO_4/5 mℓ at 530 nm (0.02 - 0.6 µg SO_4/5 mℓ at 332 nm)	Ion exchange required to remove cation and anion interferences.

Table 3-16. Specific Anion Measurement Methods (Continued)

Ion	Measurement Method	Minimum Mass Measured	Interferences/Remedies
NO_3^- (NO_x^-)	Colorimetric via reaction with 1-amino-pyrene in 75% H_2SO_4	~1 µg NO_3/5 mℓ	More sensitive than phenol-disulfonic acid reagent
NO_2^-	Colorimetric via reaction with diazotization and coupling reagents - NO_3 can also be done after reduction (with Cd, per. ex)	$\lesssim$1 ug NO_2/5 mℓ for various reagents (p-nitro aniline plus azulene, per ex.)	More sensitive than Griess-Salzman reagents.

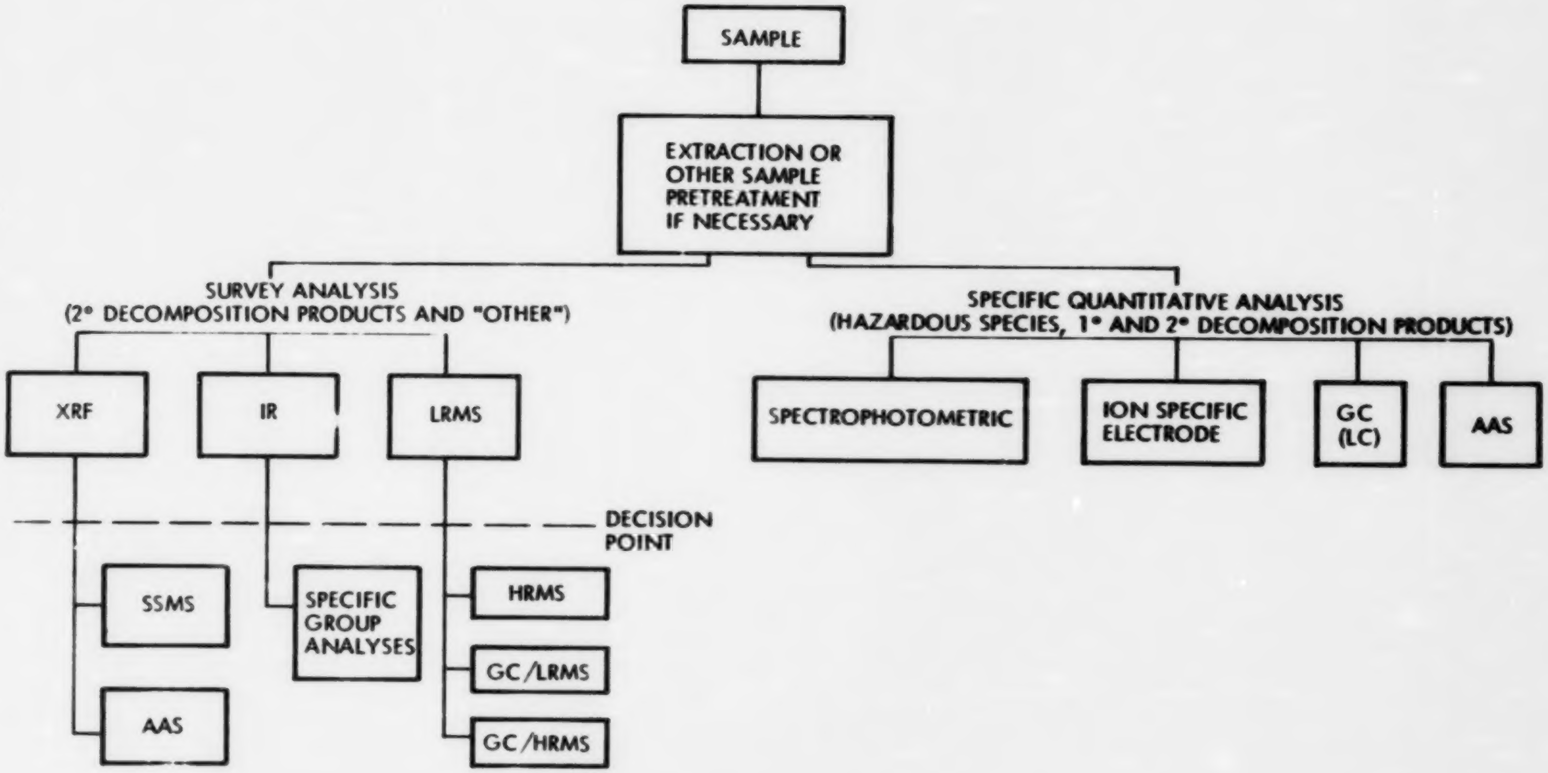

SAMPLE
EXTRACTION OR OTHER SAMPLE PRETREATMENT IF NECESSARY
SURVEY ANALYSIS
(2° DECOMPOSITION PRODUCTS AND "OTHER")
XRF
IR
LRMS
DECISION POINT
SSMS
AAS
SPECIFIC GROUP ANALYSES
HRMS
GC/LRMS
GC/HRMS
SPECIFIC QUANTITATIVE ANALYSIS
(HAZARDOUS SPECIES, 1° AND 2° DECOMPOSITION PRODUCTS)
SPECTROPHOTOMETRIC
ION SPECIFIC ELECTRODE
GC (LC)
AAS

Figure 3-7. Generalized Sample Analysis Scheme

Survey Branch

It will be necessary to conduct survey analyses on all samples to search for unexpected trace metals, functional groups, and the multitude of secondary and other decomposition products. The techniques of X-ray fluorescence (XRF), infrared spectroscopy (IR) and low resolution mass spectrometry (LRMS) are most effective and efficient for that purpose. All three assays should be conducted for each sample. The results of the survey analysis provide a decision point where the need to proceed on more detailed analysis will be determined. If a variety of metals are present, a spark source mass spectrometric (SSMS) analysis would be the most efficient means of providing the desired quantitative data. If only one or two elements are found, these may be quanitified by AAS. Low resolution mass spectrometry (LRMS) is one of the most effectual means of screening samples to determine the nature of the organic species present. When only a few compounds are present, their structure may frequently be assigned without any further analysis. For more complex samples the composition may be determined either by high resolution mass spectrometry (HRMS) which provides the additional elemental composition data, or by coupled GC/MS techniques. The choice between these methods will be dependent on the nature of the sample.

Analysis for Known Components

For many of the samples it will be necessary to rely on the analysis of hetero elements of unique groups such as P, Cl, S, CN. These would most probably be done using spectrometric and ion specific electrode (ISE) methods. Atomic absorption spectrometry (AAS) provides the most accurate means for determining specific metals. AAS is only expected to be used when metals were found in the waste stream. Gas chromatography (GC) is expected to be the single most appropriate technique to use for the analysis of the multitude of organic species to be encountered in the study. In cases where it would be more appropriate, liquid chromatography (LC) would be used in place of GC.

Additional functional groups revealed in the infrared (IR) spectrum may be analyzed by appropriate methods, usually colorimetric, if necessary. The detection limits of each of the suggested analytical techniques varies between technique and for specific compounds. Sufficient sample will be collected and analyzed to provide equivalent detection limits for trace species. All of the data on the emissions samples will have to be compared with the background for the facility in the absence of the waste stream being studied. This will be particularly important for the analysis of the scrubber samples.

Selection of Detection Measurement Limits

Many of the hazardous waste streams will give rise to products similar to those derived from burning auxiliary fuel and it will be necessary to be certain to interpret analytical results in terms of the species unique to the particular waste. In this context it will be necessary to establish some analytical measurement cut-off criteria in order to avoid trying to make quantitative measurements in the chemical "noise" of the facility and below any level of concern. The published lists of toxic substances and standards such as the OSHA standards, EPA water quality standards and the HEW toxic substances list provide some guidance in this area. Further, many local regulatory agencies consider the OSHA standards to be appropriate criteria when evaluating stationary source emissions for which no EPA standards exist. In examining the OSHA standards list (29 CFR 1910.93) one sees that the lowest value normally assigned to the most hazardous species is 0.1 mg/m^3. This concentration is therefore suggested as a cut-off level for the sample analyses. Further, data obtained in this manner will allow an evaluation of the emissions from the facility independent of a destruction ratio value.

3.5 PHASE II IMPLEMENTATION

Phase II is relatively complex from the viewpoint of effective project scheduling, control, and logistical support. The complexity results from: (1) subcontracting for test burns at 14 separate destruction facilities of various generic types; (2) acquiring some 50 different wastes for the test burns; (3) fielding and coordinating self-sufficient sampling crews at the facilities, as well as, (4) analyzing and evaluating hundreds of solid, liquid and gaseous samples. This section provides an overview of the organization, management, scheduling, procurement (including subcontracting), and project report documentation.

3.5.1 Organization and Management

TRW Systems will be the prime contractor to EPA/OSWMP for Phase II. As in Phase I, Arthur D. Little, Inc., will be associated with TRW as a major subcontractor in the performance of the technical effort. The project organization for Phase II showing the relationship of the two companies is diagrammed in Figure 3-8.

Continuity between Phases I and II is maintained by utilizing the same cadre of personnel. The TRW Project Manager is Mr. B. J. Matthews. The technical effort is divided into two teams. The TRW team is headed by Mr. R. J. Johnson, while Mr. J. I. Stevens is responsible for the ADL team. Each team has identical technical areas of responsibility; namely, field sampling, laboratory analysis and data evaluation. Responsible individuals have been identified for each of these tasks within TRW and ADL.

Integrating and coordinating the activities for both teams is the responsibility of Mr. Matthews. This is identified in Figure 3-8 as Project Control and Logistics. In this regard, TRW will be responsible for the ADL subcontract as well as all facility subcontracts and waste acquisition for both teams. Effective implementation and control of Phase II centers on this activity.

The concept of the Core Team initiated in Phase I will be continued in Phase II. Although makeup of the Core Team will vary with meeting agendas, the primary members will be two individuals each from EPA, TRW and ADL as indicated in Figure 3-8. It is anticipated that the function of the Core Team will remain essentially unchanged from Phase I. It will continue to be an effective vehicle for project communication, review, problem discussions and technical adjustments throughout Phase II.

In addition to serving as a Core Team member, Dr. R. S. Ottinger, Phase I Project Manager, and recently transferred to TRW's Operations in Washington, D.C., will provide close liaison with the EPA Project Officer, Mr. J. L. Schaum. This liaison responsibility will assist in maintaining project continuity and will facilitate communications between TRW and EPA.

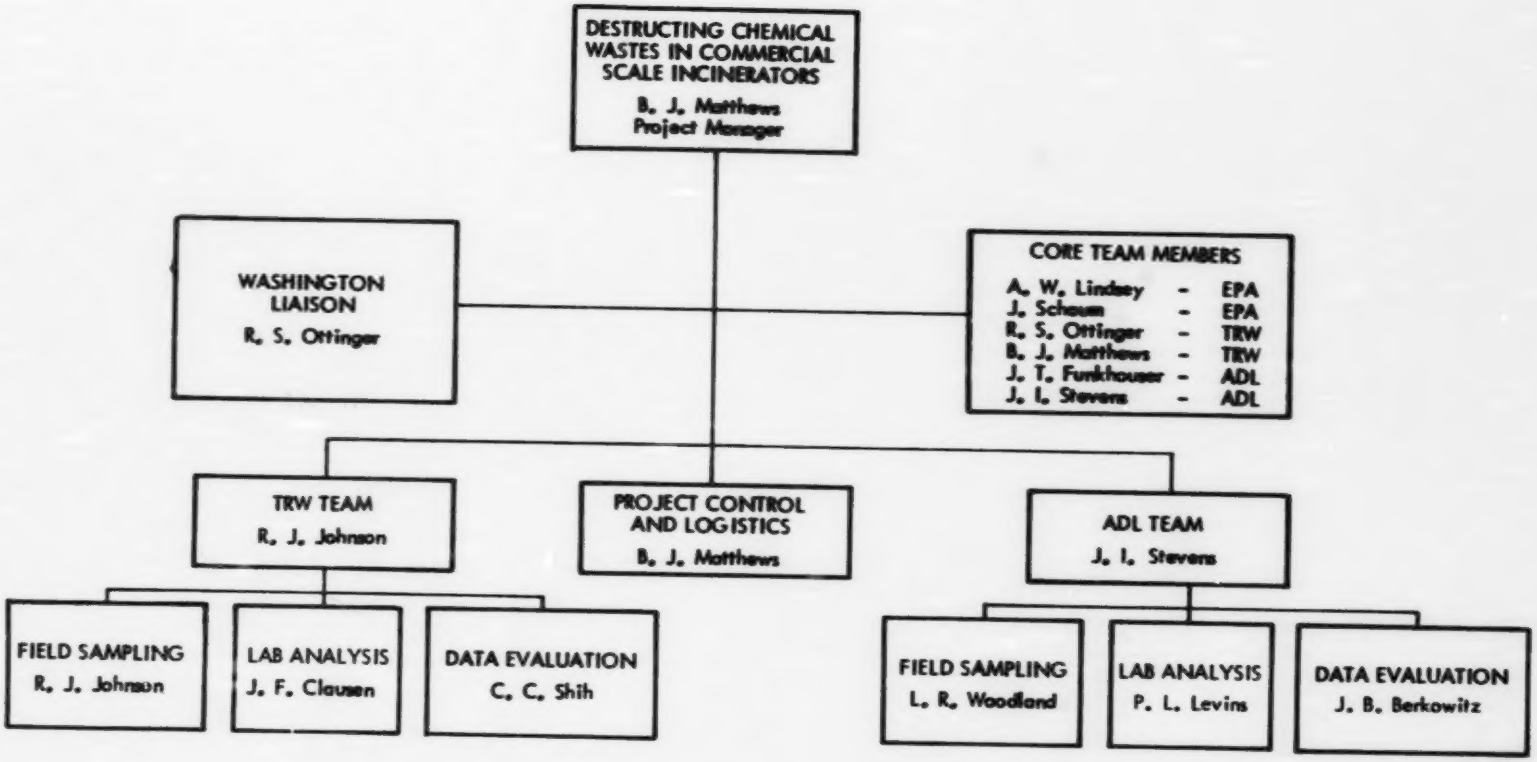


Figure 3-8. Phase II Project Organization

3.5.2 Project Schedule

The anticipated schedule of facility test burns together with related meetings and reports is shown in Figure 3-9. Laboratory analytical support is shown as a level of effort throughout the test program. The overall Phase II effort is expected to require 22 months instead of the original 18 months contemplated at the initiation of Phase I. This is due to the amount of activity time associated with each facility test burn (based upon 50 wastes), and interim time between facility tests to refurbish equipment and transfer crews and instrumentation to subsequent facility sites.

The initial 4 months of the project is concerned with preparation for field testing. The following activities will be accomplished during this period:

- Procurement of long lead time monitoring instrumentation
- Buildup and checkout of instrumentation trailers for the field tests
- Development of sampling procedures
- Design, fabrication and checkout of sampling and temperature probes
- Evaluation of analytical methods
- Securing definitive waste data and properties
- Developing an environmental impact assessment protocol for waste test burns
- Completing negotiations for the initial two facilities
- Securing wastes for the initial two facility test programs.

The facility test operations have been roughly divided in half between TRW and ADL. Six facilities will be utilized by TRW and eight by ADL. Division of the facilities is based largely upon geography, with TRW concentrating on those located in the West and Mid-west. Conversely, ADL will work with those facilities in the eastern half of the United States. The map in Figure 3-10 shows the facility locations for TRW and ADL, respectively.

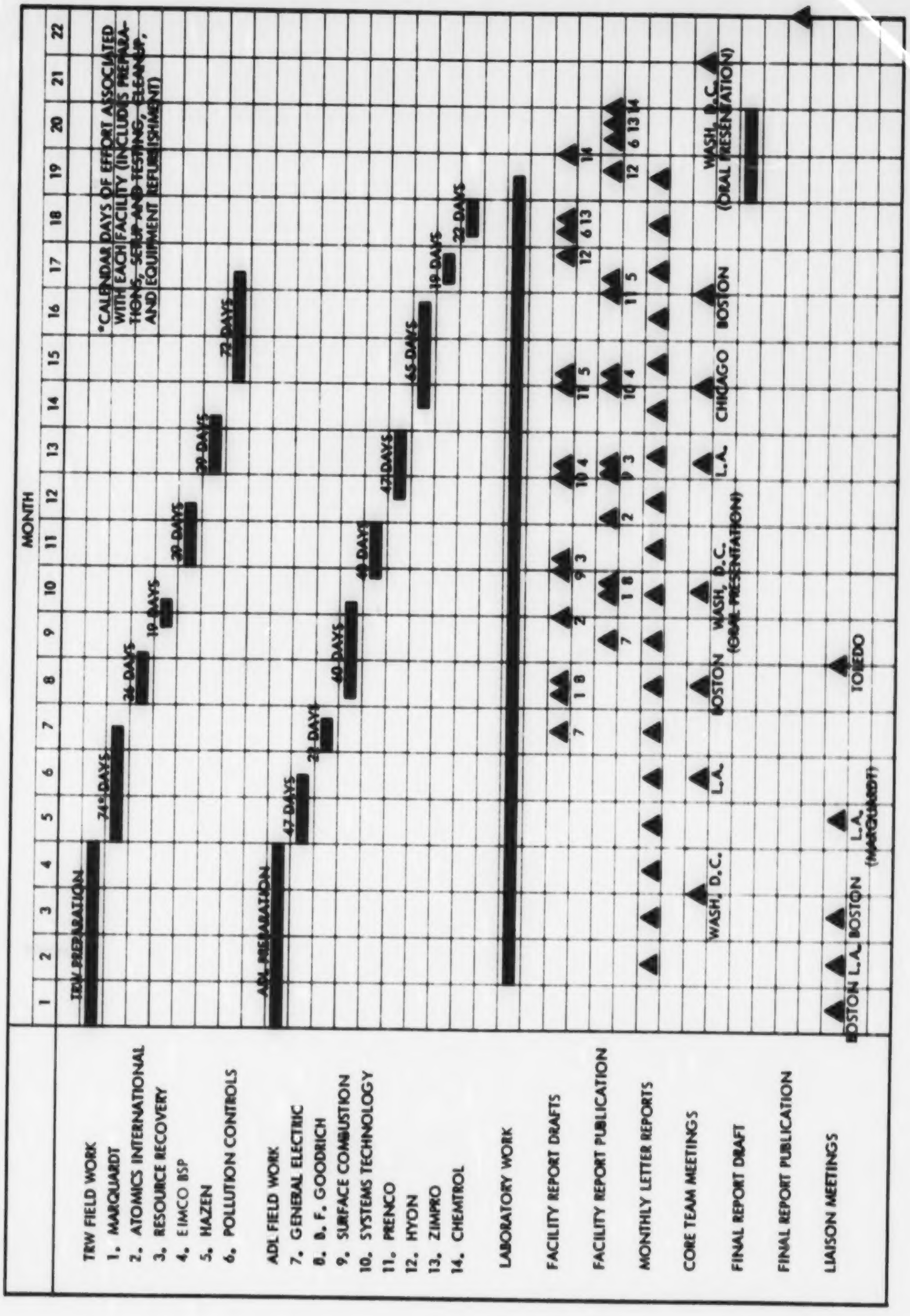


Figure 3-9. Phase II Project Schedule

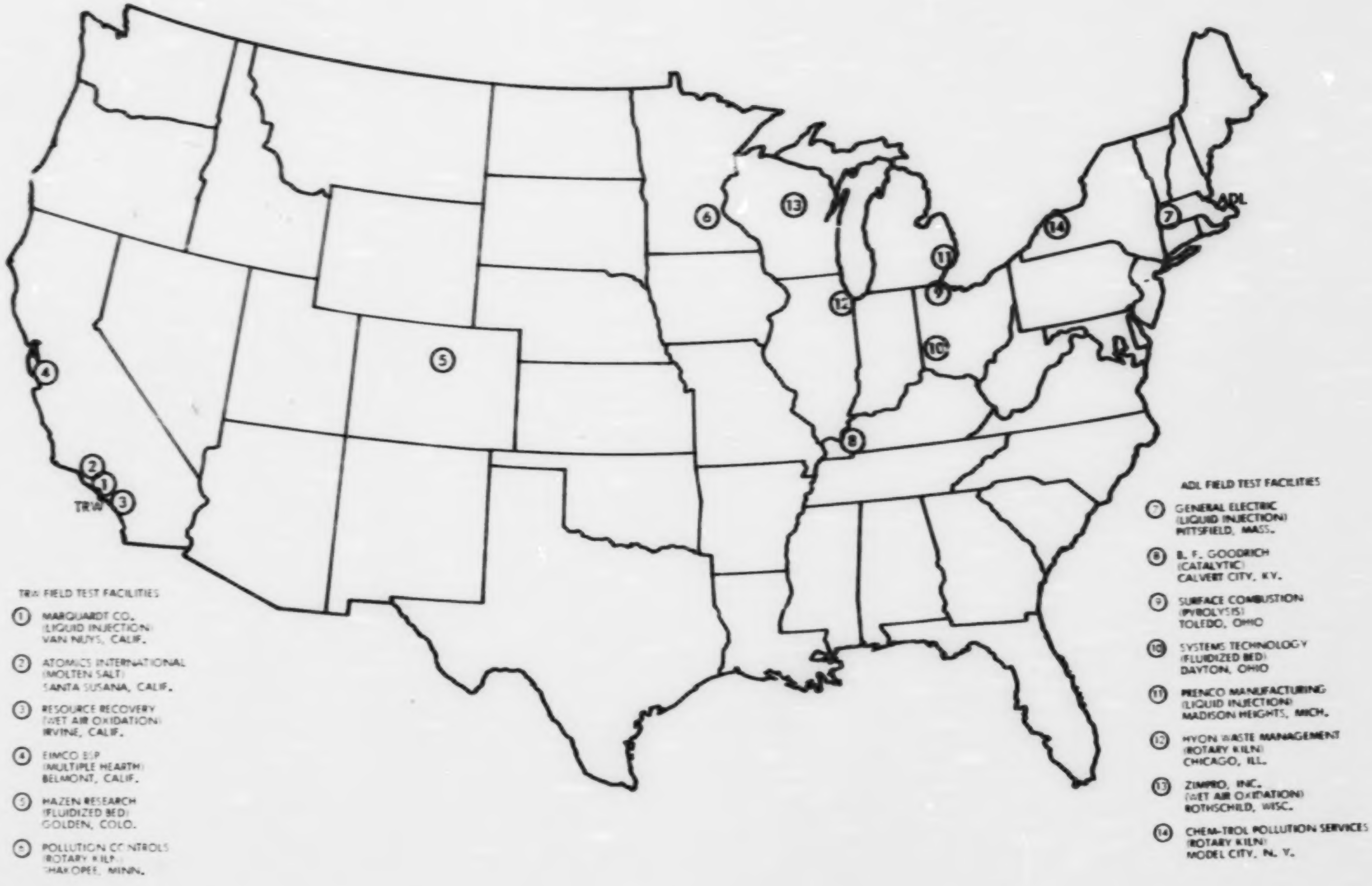

TRW
ADL
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
⑭
TRW FIELD TEST FACILITIES
① MARQUARDT CO. (LIQUID INJECTION) VAN NUYS, CALIF.
② ATOMICS INTERNATIONAL (MOLTEN SALT) SANTA SUSANA, CALIF.
③ RESOURCE RECOVERY (WET AIR OXIDATION) IRVINE, CALIF.
④ EIMCO BSP (MULTIPLE HEARTH) BELMONT, CALIF.
⑤ HAZEN RESEARCH (FLUIDIZED BED) GOLDEN, COLO.
⑥ POLLUTION CONTROLS (ROTARY KILN) SHAKOPEE, MINN.
ADL FIELD TEST FACILITIES
⑦ GENERAL ELECTRIC (LIQUID INJECTION) PITTSFIELD, MASS.
⑧ B. F. GOODRICH (CATALYTIC) CALVERT CITY, KY.
⑨ SURFACE COMBUSTION (PYROLYSIS) TOLEDO, OHIO
⑩ SYSTEMS TECHNOLOGY (FLUIDIZED BED) DAYTON, OHIO
⑪ PRENCO MANUFACTURING (LIQUID INJECTION) MADISON HEIGHTS, MICH.
⑫ HYON WASTE MANAGEMENT (ROTARY KILN) CHICAGO, ILL.
⑬ ZIMPRO, INC. (WET AIR OXIDATION) ROTHSCHILD, WISC.
⑭ CHEM-TROL POLLUTION SERVICES (ROTARY KILN) MODEL CITY, N. Y.

Figure 3-10. Location of Facilities to be Used by TRW and ADL in Phase II Testing

Although ADL has two more facilities than TRW, the overall work load is approximately balanced due to the fact that two of ADL's facilities (Chem-Trol and B. F. Goodrich) will process only one waste each at a single test condition. It is anticipated that the actual test operations will require approximately 14 months to complete. The final 2 months of the technical effort are devoted to finishing laboratory analyses from the last two facilities and preparation of the final report draft.

The present schedule calls for eight Core Team meetings during the program. Additional meetings can be convened if the situation warrants. The initial Core Team meeting is scheduled at the end of the third month to review and assess the status of the preparation effort. It will be used largely to evaluate progress, assure continuity of effort between TRW and ADL, and review plans for the initial two facility test programs. Subsequent Core Team meetings are planned to coincide with specific facility test burns. Oral project reviews are planned for the mid-point and end of the Phase II effort. These will be held in Washington, D.C.

In addition to the Core Team meetings, liaison meetings are scheduled on approximately a monthly basis during the first several months of the Phase II work. These are for the purpose of coordinating the TRW and ADL sampling and analytical procedures. This is key to the acquisition of comparable data from the sampling and analysis teams of the two companies.

As indicated previously, negotiations and scheduling of the facilities, as well as waste acquisition for the first two test burns, will be accomplished during the preparation period of work. As soon as these arrangements are completed, the second set of facilities and wastes to be tested will be negotiated and scheduled. Successive facilities and wastes will be negotiated and procured in turn. A lead time for negotiations with facilities and procurement as well as transportation of wastes to the test sites is estimated to require 3 months at a minimum. This time is required for finalizing all technical interfaces at facilities (through site visits), negotiations with the facilities, and subcontract approval by EPA. Lead time is also required for waste acquisition to allow for waste sample analysis by the TRW and ADL laboratories, and waste procurement and transportation to the facility site. In this regard, most facilities will also require time to perform routine waste analyses, pretreatment, and facility modifications as required.

3.5.3 Documentation and Reporting

Reports for Phase II fall into three categories. It is anticipated that monthly technical progress letters and financial status reports will be issued to the EPA Project Officer. These will be brief summaries of progress and problem areas encountered during the monthly reporting period. In addition, 14 facility reports will be issued covering all aspects of the facility test program operations. The content of these reports is outlined in the facility test plans in Volume II of this Phase I report. These documents will be self-contained. Drafts of the reports will be submitted for EPA approval 30 days after completion of all work associated with a facility test burn operation (including data analyses and evaluation). The cycle for EPA approval and subsequent publication of the facility reports will be another 2 months, and finally, a summary report of the entire Phase II effort will be prepared and submitted to EPA for approval. Publication of the approved version of this final report is scheduled for the end of the 22nd month of the program.

3.5.4 Subcontracting and Procurement

A very significant portion of the overall Phase II cost will be expended on subcontracts and for purchased items or services. Timely implementation of project activities is dependent upon a coordinated subcontracting and procurement plan. The TRW Materiel Organization will perform these tasks at the request and guidance of the Project Manager. The Materiel Organization provides centralized purchasing, inventory handling, legal counseling, and all related expediting functions. For the Phase II effort, the Materiel Organization has assigned two subcontract administrators to support the Project Manager. The senior of these serves as a single point of contact and authority to assure that the procurement system is responsive to the project's needs. The major procurement activities for Phase II are summarized briefly in the following text.

- The subcontract to Arthur D. Little, Inc., is the most significant and highest value procurement in Phase II. A cost plus fixed fee subcontract is contemplated for Phase II to provide the operational flexibility essential to its effective execution. The ADL subcontract will be negotiated, awarded, and managed by a subcontract administrator assigned from the TRW Materiel Organization.

- The fourteen destructor facility subcontractors represent a spectrum ranging from sophisticated aerospace industry companies to purely commercial firms having little or no expertise or experience in a Government contracting environment. The subcontractor selection rationale is discussed elsewhere in this report. From preliminary proposal evaluations and negotiations, it is likely that cost plus fixed fee subcontracts will be appropriate in most cases. It is apparent that some exceptions to this general condition may occur. It will be necessary to assess the accounting system capabilities of some of these subcontractors before a determination of the appropriate subcontract type can be made. These assessments will be made during the planned facility surveys. All of the destructor facility subcontracts will be negotiated, awarded and managed from within the Materiel Organization.

- Acquisition of the fifty wastes is expected to encompass a range from simple no-cost agreements to purchase orders for relatively low-dollar costs for special handling, packaging and transportation tasks. Firm fixed price purchase orders are contemplated. These procurements will be accomplished by a procurement specialist in the Central Purchasing Organization, who specializes in the procurement and disposal of hazardous materials and products. Well-established routines exist for the specialized coordination and control (involving the TRW Purchasing, Health and Safety, and Traffic organizations) associated with this type of procurement.

- Disposal of hazardous residual material samples will also be contracted for by the procurement specialist described in the preceding paragraph. The same precautions and controls applicable to procurement will be exercised for this disposal task.

- A portion of the routine laboratory analysis of waste stream samples will be subcontracted. Utilizing normal competitive bidding practices, appropriate laboratories will be selected and awarded blanket or "call" type purchase orders. Analysis of specific samples will be accomplished under releases against these blanket orders. TRW's blanket order release system is compatible with the controls required for the handling of hazardous substances.

Unique Procurement Considerations

Consistent with the "Competition in Subcontracting" clause of EPA's General Provisions, TRW's procurement system and Materiel Organization are heavily oriented to the objectives of competitive bidding. The TRW system has the flexibility to deal with unique characteristics and requirements of specific programs. In the case of this project, the proposed subcontractors and waste stream sources were selected on the basis of predominantly technical considerations consistent with the fundamental objectives of the Phase II effort. These recommendations are the result of engineering evaluations and analyses carried out during Phase I and were the subject of Core Team coordination. Accordingly, TRW recommends that the subcontractors and waste stream sources described in this report be identified in the Phase II contract as directed sources.

- Several destructor facility bidders have indicated concern regarding liability and/or allowability of cost of special liability insurance premiums. As negotiations mature, other subcontractors and waste stream suppliers will most likely raise similar questions. In the environment of the complex network of interrelated tasks of types never before undertaken, lengthy negotiations centering on these questions probably will occur. An impasse in such a case could effectively defeat a major Phase II objective. Assuming agreement is possible, it is the experience of TRW's procurement personnel and legal counsel that the numerous protracted discussions leading to agreement of such matters are substantially more time consuming than arriving at equitable price and schedule agreements. This condition frequently results in inordinate delays in awarding subcontracts. TRW, therefore, strongly recommends that the Phase II contract include a clause or article such as "Insurance - Liability to Third Persons," recently authorized for use by the EPA. Also, we request that TRW be specifically authorized to include such a clause in appropriate subcontracts and that the Phase II contract contain a provision recognizing cost or expense incurred by TRW thereunder as an allowable cost.

Authorization and Control

The day-to-day responsibility for procurement (i.e., identification of need, description of the hardware or service and associated schedules, initiation of the procurement documentation, control of the program budget, and management of the day-to-day activities) is placed within the Logistics Group of the Applied Technology Division Materiel Organization. This group will provide material planning, consolidation of requirements, purchasing follow-up, status reporting, receiving, storage, in-plant routing, and maintenance of appropriate records.

The Logistics Group Planner will identify requirements and develop schedules in conjunction with the TRW Project Office. He will generate purchase requisitions, highlight problems, and ensure prompt resolution by appropriate resources.

Purchase requisitions initiated by the planner will be accompanied by the handling, packaging, marking and shipping instructions which will be developed specifically for Phase II of the Hazardous Waste Disposal Program.

3.5.5 Potential Problems

Problems during Phase II are anticipated due to the experimental and demonstration nature of the work. As in Phase I, the Core Team concept will be utilized to effectively deal with problems as they arise. In addition to the basic members, administrative and technical specialists from TRW and ADL are available to augment the Core Team composition at any given time and participate in resolving major problems.

Wastes

Uncertainties related to the composition and properties of selected wastes constitute a potential problem area. Data at this point in time are sparse, and, therefore, waste handling, pretreatment, and expected combustion characteristics cannot be precisely defined. Pretest burn waste sample analyses will resolve many of these uncertainties.

A more significant problem is that firm written commitments for ten of the 50 selected wastes have not yet been obtained. Two major waste sources are still considering participation in the Phase II effort. If one or both of these waste sources agrees to participate, there will be minimal problems in obtaining the needed wastes. Should both sources decline, alternate wastes will have to be selected from the remaining waste streams identified during Phase I. In the interim, contact with the two important waste sources is being maintained in an effort to solicit their cooperation.

Facilities

Some problems associated with the facilities can be anticipated. Equipment failures and breakdowns will no doubt occur. To the extent possible, these considerations have been taken into account in scheduling activities at the various test sites.

Should final negotiations with one or more of the thermal destruction facilities be terminated unsuccessfully, alternates are readily available in all categories with the exceptions of multiple hearth, molten salt, and catalytic units. In the case of multiple hearths, arrangements could probably be made to use a municipal unit. Although test conditions and experimental control would be less than ideal, this could be a viable option. With regard to molten salt, at least one other unit (Battelle Northwest) is available; however, this is only a bench scale system. No alternate catalytic and thermal systems are known to be available at this time. Should a facility now planned for use in Phase II become unavailable, alternate facilities will be contacted and integrated into the demonstration program.

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APPENDIX A

WASTE/FACILITY MATCHING MATRICES

The following work sheets were utilized in the matching of wastes to destruction facilities as described in Section 3.3.

1

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Ethylene glycol manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
~~5000-10000 Btu/#,~~
[✓ Below 5000 Btu/#]

WASTE STREAM		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	3	3	2	3	2

ADDITIONAL CRITERIA AND REMARKS:
Waste stream is mixture of water and glycols and generated in large volumes. Liquid injection is selected as the facility type for waste destruction. Fluidized bed incineration may also be considered.

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H

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: off-specification isoprene

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#]
5000-10000 Btu/#
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)	/	/	■	/	/	/	■	/	/
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder		■			■				■
	Tarry		■	■		■			■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							■		
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	③	2	3	3	3	2	3	2

ADDITIONAL CRITERIA AND REMARKS:

Isoprene is an unstable oxidizable liquid and should only be handled in smaller quantities by individuals experienced in dealing with flammable and explosive materials. Marquardt's liquid injection facility is selected for this reason

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Off-specification phenol

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F	/	▨	▨	▨	▨	▨	▨	▨	/
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	2	③	3

ADDITIONAL CRITERIA AND REMARKS:
Systems Tech claimed to have access to large supplies of off-spec phenol and for this reason is selected as the waste destruction facility

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Evaporator residue from the cumene process for phenol manufacture

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	1	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Phenol waste may be too hazardous to be handled at a pyrolysis facility. Molten salt is not too suitable for handling tarry wastes. Rotary kiln is selected.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

LASSIFICATION: H-C and H-C-O

ESCRIPTION: API separator bottoms

EATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE		/	▨	/	/	▨	/	/	/	▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	3	3	2	3	③	3	1

ADDITIONAL CRITERIA AND REMARKS:

Pyrolysis is selected as the facility type for waste destruction because of resource recovery (as fuel) potential and relatively low toxicity of the waste

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Waste residue from alkylbenzene production

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#],
5000-10000 Btu/#,
Below 5000 Btu/#

WASTE STREAM		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	1	1	▨	1	1	1	▨	1	1
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	1	1	▨	1	▨	▨	1	▨	▨
	1400-2000°F	1		1		▨	1		1	▨
	700-1400°F	1	▨	▨	▨	1		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	1	1	1	1	1	1	1	1	1
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	[✓ 3]	2	3	3	3	2	3	2

ADDITIONAL CRITERIA AND REMARKS:
This is a large volume liquid waste. A large liquid injection facility such as GE or Prenco is selected

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Tars from production of styrene

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
~~5000-10000 Btu/#.~~
Below 5000 Btu/#

WASTE STREAM		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Pyrolysis is selected as the facility type for waste destruction because of the resource recovery (as fuel) potential and relatively low toxicity of the waste.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Rubber manufacture waste sludge

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE		/	▨	/	/	▨	/	/	/	▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	3	3	1	3	[✓ 3]	3	1

ADDITIONAL CRITERIA AND REMARKS:

Pyrolysis is selected as the facility type for waste destruction because of the resource recovery (as fuel) potential and relatively low toxicity of the waste. The waste has also been reported as difficult to incinerate

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Isophthalic and terephthalic acid still bottoms

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)			■				■		
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder	/	■	/	/	■	/	/	/	■
	Tarry		■	■		■			■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							■		
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	2	③	3.	2	3	3	3	1

ADDITIONAL CRITERIA AND REMARKS:
Multiple hearth is the facility type selected for waste destruction, because this is one of the few waste streams that could be handled by multiple hearth.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM			FACILITY TYPE							
CLASSIFICATION: H-C ~~and~~ H-C-O DESCRIPTION: Ethylene manufacturing wastes HEATING VALUE (CIRCLE ONE) [✓ Above 10,000 Btu/#,] 5000-10000 Btu/#, Below 5000 Btu/#		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)	/	/	■	/	/	/	■	/	/
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder		■			■				■
	Tarry		■	■		■			■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							■		
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	3	2	3	3	3	2	③	2

ADDITIONAL CRITERIA AND REMARKS:

This is one of the few large volume wastes suitable for fluidized bed incineration. Systems Tech is the destruction facility selected.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Organic peroxide manufacturing wastes

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	2	③	2

ADDITIONAL CRITERIA AND REMARKS:

This waste has high sodium content and is more suitable for fluidized bed incineration than liquid injection incineration. The waste generation source has indicated problems in waste incineration.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Tars from production of phthalic anhydride (xylene process)

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)			■				■		
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder		■			■				■
	Tarry	/	■	■	/	■	/	/	■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							■		
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	2	2	3	2	3	[✓ 3]	2	1

ADDITIONAL CRITERIA AND REMARKS:

Pyrolysis is selected as the facility type for waste destruction because of the potential for resource recovery (as fuel) and the relatively low toxicity of the waste

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C and H-C-O

DESCRIPTION: Still bottoms from acetaldehyde production and byproduct recovery operation

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	✓	✓	▨	✓	✓	✓	▨	✓	✓
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	✓	✓	▨	✓	▨	▨	✓	▨	▨
	1400-2000°F	✓		✓		▨	✓		✓	▨
	700-1400°F	✓	▨	▨	▨	✓		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	3	3	2	3	2

ADDITIONAL CRITERIA AND REMARKS:

Waste stream is generated in large volumes and suitable for disposal in a large liquid injection incineration facility such as GE or Pernco

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Steam still bottoms from aniline and alkylated phenol production

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	✓	▨	▨	✓	▨	✓	✓	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	✓	✓	▨	✓	▨	▨	✓	▨	▨
	1400-2000°F	✓		✓		▨	✓		✓	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	1	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction. Molten salt is not very suitable for the disposal of tarry wastes. Pyrolysis may also be considered

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Catch basin grease, nitrile pitch from production of surface active agents.

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#],
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction. Pyrolysis may also be considered.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Solid residue from manufacture of aromatic amines

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE							
			LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		▨
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder	/	▨	/	/	▨	/	/	/	▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/			▨
	700-1400°F		▨	▨	▨			▨	/	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	▨
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	③	3	1	3	3	3	1

ADDITIONAL CRITERIA AND REMARKS:

This is one of the few wastes suitable for disposal by multiple hearth incineration. Multiple hearth is selected

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Carbaryl manufacturing waste

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

WASTE STREAM		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	2	③	2

ADDITIONAL CRITERIA AND REMARKS:

This is one of the few large volume wastes suitable for disposal by fluidized bed incineration Systems Tech is the waste facility selected

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Reactor tar bottoms from adiponitrile manufacture

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	1	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction. Waste may also contain phosphoric acid.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Acrylonitrile manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: TDI manufacture reactor tar bottoms

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

WASTE STREAM		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)			■				■		
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder		■			■				■
	Tarry	/	■	■	/	■	/	/	■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							■		
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	2	2	③	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:
Rotary kiln is selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Diphenylamine (DPA) manufacture reactor tar bottoms

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

FACILITY TYPE

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: wastes from toluene-diamine (TDA) production from dinitrotoluene (DNT)

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)	/	▨	▨	/	▨	/	▨	/	/
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2-	3	2	③	2

ADDITIONAL CRITERIA AND REMARKS:

Fluidized bed is selected as the facility type for waste destruction. Systems Tech as the waste facility selected because waste is generated in sufficiently large quantities.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Dinitrophenol wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE							
			LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU	/	▨	▨	/	▨	/	▨	/	/
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/			▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F	/	▨	▨	▨	▨	▨	▨	▨	/
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2	3	2	2	[✓ 3]

ADDITIONAL CRITERIA AND REMARKS:
Waste stream is still bottom residue from dyestuff intermediates, and sets up to a semi-solid inside drums. Wet air oxidation is selected as the facility type for waste destruction because similar types of wastes have been successfully destroyed by wet air oxidation.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: DNT/MNT mix from DNT production

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE		/	▨	/	/	▨	/	/	/	▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	3	3	2	③	3	3	1

ADDITIONAL CRITERIA AND REMARKS: Waste sludge may also contain TNT and is potentially explosive. Molten salt is therefore selected as the facility type for waste destruction.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: Phenylamine tar wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	✓	▨	▨	✓	▨	✓	✓	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	✓	✓	▨	✓	▨	▨	✓	▨	▨
	1400-2000°F	✓		✓		▨	✓		✓	▨
	700-1400°F	✓	▨	▨	▨	✓		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	3	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction.

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-N and H-C-N-O

DESCRIPTION: wastes from polymer polyol production from polymerization of styrene with acrylonitrile

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	3	3	2	3	2

ADDITIONAL CRITERIA AND REMARKS:

Liquid injection is selected as the facility type for waste destruction. Fluidized bed incineration may also be considered.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Vinyl chloride monomer manufacturing wastes

HEATING VALUE (CIRCLE ONE)
~~Above 10,000 Btu/#,~~
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	③	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS:

Goodrich at Calvert City generates this waste stream and is operating a catalytic fluidized bed ([illegible] reactor) for the destruction of this waste stream. Since Goodrich is the only catalytic incineration facility available and will only accept the vinyl chloride monomer waste this particulate waste is assigned to the Goodrich facility.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Organic chemical, capacitor and transformer production wastes containing PCB's and alpha methylstyrene

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
5000-10000 Btu/#,
[✓ Below 5000 Btu/#]

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU	/	▨	▨	/	▨	/	▨	/	/
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	1	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: Wastes are capacitors containing paper impregnated by PCB's and free PCB liquid. Monsanto will not accept this waste for incineration at its Sauget, Illinois facility. Rotary kiln is selected as the facility type for waste destruction. Molten salt may also be considered since waste is mixture of large solids and liquid, fluidized bed incineration is not suitable

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Reactor bottoms from PVC manufacture

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder	✓	▨	✓	✓	▨	✓	✓	✓	▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	✓	✓	▨	✓	▨	▨	✓	▨	▨
	1400-2000°F	✓		✓		▨	✓		✓	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	✓	✓	✓	✓	✓	✓	▨	✓	✓
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	[✓ 3]	3	1	3	2	3	1

ADDITIONAL CRITERIA AND REMARKS:
Multiple hearth is the facility type selected because this is one of the few wastes suitable for destruction by multiple hearth

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MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Epichlorohydrin manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	✓	▨	▨	✓	▨	✓	✓	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	✓	✓	▨	✓	▨	▨	✓	▨	▨
	1400-2000°F	✓		✓		▨	✓		✓	▨
	700-1400°F	✓	▨	▨	▨	✓		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	✓	✓	✓	✓	✓	✓	▨	✓	✓
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	2	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Wastes from perchloroethylene production

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

WASTE STREAM		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	3	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: This is a large volume liquid waste liquid injection is the facility type selected for waste destruction. Trenco or GE is the waste facility selected

3

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: HC-Cl and H-C-Cl-C

DESCRIPTION: Hexachlorocyclopentadiene manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	3	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: Liquid injection is the facility type selected for waste destruction. This is one of the two chlorinated hydrocarbon wastes selected for liquid injection incineration. Since the perchloroethylene waste has been assigned to Prenco or GE, this particular waste is assigned to Marquardt

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O
DESCRIPTION: Phenolic tar from 2,4-D manufacture

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	[✓ 3]	2	3	2	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction.

3.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Organic pharmaceutical wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 6000-10000 Btu/#,]
Below 5000 Btu/#

WASTE STREAM			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)	/	▨	▨	/	▨	/	▨	/	/
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2	3	1	③	2

ADDITIONAL CRITERIA AND REMARKS:

Fluidized bed is selected as the facility type for waste destruction.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-Cl-O

DESCRIPTION: Chlorotoluene production wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	2	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste selection

3c

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: H-C-Cl and H-C-Cl-O

DESCRIPTION: Phenolic tar from MCPA (4-Chloro-2-methyl-phenoxyacetic acid) manufacture

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
[✓ 5000-10000 Btu/#.]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	3	2	[✓ 3]	2	2	1

ADDITIONAL CRITERIA AND REMARKS: MCPA (4-Chloro-2-methylphenoxyacetic acid) is similar in chemical structure to 2,4-D. 2,4-D tar waste has been assigned to rotary kiln incineration. The MCPA tar waste is therefore assigned to molten salt thermal destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-N-Cl-O

DESCRIPTION: Nitrochlorobenzene manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#,]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	2	3	2	2	1

ADDITIONAL CRITERIA AND REMARKS:

Rotary kiln is selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-N-Cl-O

DESCRIPTION: Amiben manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
5000-10000 Btu/#,
[✓ Below 5000 Btu/#]

WASTE STREAM		FACILITY TYPE								
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	1	③	2

ADDITIONAL CRITERIA AND REMARKS:

This is a large volume waste containing 90% water, 5% isomers of Amiben and 5% NaCl and Na_2SO_4. Fluidized bed is selected as the facility type for waste destruction because of high water content and high sodium salt content.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-N-Cl

DESCRIPTION: Dichloroaniline still bottoms

HEATING VALUE (CIRCLE ONE)
~~Above 10,000 Btu/#.~~
[✓ 5000-10000 Btu/#.]
~~Below 5000 Btu/#~~

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder	/	▨	/	/	▨	/	/	/	▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	3	3	1	[✓ 3]	2	3	1

ADDITIONAL CRITERIA AND REMARKS:
Molten salt is selected as the facility type for waste destruction because this particular waste is difficult to incinerate

4c

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-S-O

DESCRIPTION: Alkyl and aryl sulfonic acid wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
			FACILITY TYPE							
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	2	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: waste is mixture of emulsified oil and sulfones. Liquid injection is selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-S-N

DESCRIPTION: Mercaptobenzothiazole (MBT) manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
5000-10000 Btu/#,
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)			▨				▨		
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry	/	▨	▨	/	▨	/	/	▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	2	2	③	1	3	2	2	1

ADDITIONAL CRITERIA AND REMARKS:
Rotary kiln is selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-S

DESCRIPTION: Dodecyl mercaptan manufacturing wastes

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#]
5000-10000 Btu/#,
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	2	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS:

Liquid injection is selected as the facility type for waste destruction. Marquardt is selected because this particular is generated in low volumes

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-F

DESCRIPTION: Fluorinated herbicide waste

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	2	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: This is a small volume waste and the only fluorine containing waste among the 50 selected for Phase II testing. The liquid injection incineration facility at Marquardt is selected for waste destruction.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-Br-O

DESCRIPTION: Ethylene bromide manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
			FACILITY TYPE							
GAS				■				■		■
LIQUID	Low Viscosity (Below 500 SSU)	/	/	■	/	/	/	■	/	/
	High Viscosity (Above 500 SSU)		■	■		■		■		
SLURRY	Low Viscosity (Below 500 SSU)			■		■		■		
	High Viscosity (Above 500 SSU		■	■		■		■		
SLUDGE			■			■				■
SOLID	Friable Powder		■			■				■
	Tarry		■	■		■			■	■
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	■	/	■	■	/	■	■
	1400-2000°F	/		/		■	/		/	■
	700-1400°F	/	■	■	■	/		■	■	■
	Below 700°F		■	■	■	■	■	■	■	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	■	/	/
ASH	Non Fusible					■				
	Fusible			■		■			■	
	Metallic					■				
TOTALS		3	3	2	3	3	3	1	③	2

ADDITIONAL CRITERIA AND REMARKS: This is a large volume waste and the only bromine containing waste among the 50 selected for Phase II testing. Fluidized bed incineration is the facility type selected for waste destruction. Liquid injection may also be considered.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-P-O

DESCRIPTION: Urethane manufacturing wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
~~5000-10000 Btu/#,~~
[✓ Below 5000 Btu/#]

		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	2	3	1	[✓ 3]	2

ADDITIONAL CRITERIA AND REMARKS: Waste is mixture of polyols and phosphate esters. Fluidized bed incineration is the facility type selected for waste destruction Liquid injection may also be considered.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-O-P-S

DESCRIPTION: Organophosphorus pesticides (malathion)

HEATING VALUE (CIRCLE ONE)
[✓ Above 10,000 Btu/#,]
5000-10000 Btu/#,
Below 5000 Btu/#

		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
			FACILITY TYPE							
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F		▨	▨	▨			▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	3	2	3	1	3	2

ADDITIONAL CRITERIA AND REMARKS: The off-specification malathion contains both phosphorus and sulfur. Liquid injection at Marquardt is selected waste destruction.

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-Si

DESCRIPTION: Tetraethylorthosilicate wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
[✓ 5000-10000 Btu/#]
Below 5000 Btu/#

			FACILITY TYPE							
		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F		▨	▨	▨	▨	▨	▨	▨	
OFF GASES	Essentially Oxides of C, H, N	/	/	/	/	/	/	/	/	/
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals							▨		
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	③	2	③	③	③	2	③	2

ADDITIONAL CRITERIA AND REMARKS: This is a small volume waste and the only silicon containing waste among the 50 selected for Phase II testing. Fluidized bed incineration at Hazen is selected as the waste destruction facility

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-Na-S-O

DESCRIPTION: Refinery spent caustic

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
5000-10000 Btu/#,
[✓ Below 5000 Btu/#]

WASTE STREAM		WASTE CHARACTERISTIC	FACILITY TYPE: LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F	/	▨	▨	▨	▨	▨	▨	▨	/
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	1	3	③

ADDITIONAL CRITERIA AND REMARKS: This is one of the few wastes suitable for destruction by wet air oxidation Wet air oxidation is therefore selected as the facility type for waste destruction

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-N-Cl-S-O

DESCRIPTION: Coke plant wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#,
5000-10000 Btu/#,
[✓ Below 5000 Btu/#]

WASTE STREAM		WASTE CHARACTERISTIC	FACILITY TYPE							
			LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F	/	▨	▨	▨	▨	▨	▨	▨	/
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	1	3	③

ADDITIONAL CRITERIA AND REMARKS: Wet air oxidation is selected as the facility type for waste destruction as this is one of the few wastes suitable for disposal by wet air oxidation

MATRIX FOR MATCHING WASTES AND FACILITIES

WASTE STREAM

CLASSIFICATION: C-H-N-S-O -Na

DESCRIPTION: Petroleum refining sour wastes

HEATING VALUE (CIRCLE ONE)
Above 10,000 Btu/#.
5000-10000 Btu/#.
[✓ Below 5000 Btu/#]

WASTE STREAM		WASTE CHARACTERISTIC	LIQUID INJECTION	MULTIPLE HEARTH	ROTARY KILN	CATALYTIC AND THERMAL	MOLTEN SALT	PYROLYSIS	FLUIDIZED BED	WET AIR OXIDATION
GAS				▨				▨		▨
LIQUID	Low Viscosity (Below 500 SSU)	/	/	▨	/	/	/	▨	/	/
	High Viscosity (Above 500 SSU)		▨	▨		▨		▨		
SLURRY	Low Viscosity (Below 500 SSU)			▨		▨		▨		
	High Viscosity (Above 500 SSU		▨	▨		▨		▨		
SLUDGE			▨			▨				▨
SOLID	Friable Powder		▨			▨				▨
	Tarry		▨	▨		▨			▨	▨
TEMP. RANGE FOR DESTRUCT.	Above 2000°F	/	/	▨	/	▨	▨	/	▨	▨
	1400-2000°F	/		/		▨	/		/	▨
	700-1400°F	/	▨	▨	▨	/		▨	▨	▨
	Below 700°F	/	▨	▨	▨	▨	▨	▨	▨	/
OFF GASES	Essentially Oxides of C, H, N									
	Contain Halogen, Sulfur, Phosphorus, or Volatile Metals	/	/	/	/	/	/	▨	/	/
ASH	Non Fusible					▨				
	Fusible			▨		▨			▨	
	Metallic					▨				
TOTALS		3	3	2	3	3	3	1	3	③

ADDITIONAL CRITERIA AND REMARKS: This is one of the few wastes suitable for disposal by wet air oxidation. Wet air oxidation is therefore selected as the facility type for waste destruction